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SECURITY CLASSIFICATION OF THIS PAGE (When Date Entered) READ INSTRUCTIONS BEFORE COMPLETING FORM REPORT DOCUMENTATION PAGE 2. GOVT ACCESSION NO. 3. NSWC/DL-TR-3120-Va L-2 Solution of the Integer Concave Program Using the ICON Algorithm, Volume 2. CONTRACT OR GRANT NUMBER(*) IC phi N . AUTHOR(s) Harlan W. Loomis PERFORMING ORGANIZATION NAME AND ADDRESS 61152N, ZROOKO1 Naval Surface Weapons Center (K30) Dahlgren, Virginia 22448 ZR01407 NWL/01K07 11. CONTROLLING OFFICE NAME AND ADDRESS DE 1078 Naval Surface Weapons Center (K30) 1 Novem Dahlgren, Virginia 22448 149 14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office) 15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING Approved for public release; distribution unlimited. 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) 18. SUPPLEMENTARY NOTES 19. KEY WORDS (Continue on reverse side if necessary and identify by block number) integer programming optimization theory algorithm linear programming systems analysis branch-and-bound mathematical programming computer program nonlinear programming concave function operations research convex function ASTRACT (Continue on reverse elde if necessary and identity by block number)

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ABSTRACT

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FOREWORD

Optimization problems involving integer-valued decision variables occur frequently in operations research and in systems analysis. Many cost-effectiveness analyses performed within the Department of Defense are optimization problems of this type. Specific applications related to amphibious operations occur in mine warfare, logistics, and fire support. This report presents a new method for solving a large class of integer nonlinear optimization problems.

The material presented here implements ideas developed during the author's program of studies in the Department of Operations Research, School of Engineering and Applied Science, The George Washington University, Washington, D. C. Support for this research in integer non-linear optimization and the development of computational algorithms has been provided by the Naval Surface Weapons Center's Independent Research Program. The author is presently involved in surface warfare applications of this optimization technique.

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Warfare Analysis Department

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SOLUTION OF THE INTEGER CONCAVE PROGRAM USING THE ICON ALGORITHM

VOLUME 2

1. INTRODUCTION

The ICON branch-and-bound algorithm has been implemented in the form of a computer program coded in FORTRAN for the CDC 6700 computer system. Appendices A and B of Volume 1 describe the input data and the user subroutines which are required by the program. Appendix C of Volume 1 provides descriptive examples of input data and user subroutines for three test problems. Volume 2 includes that additional information which is needed to fully document the computer program.

Although the computer program for the ICØN algorithm was developed for use on the CDC 6700 computer, a special effort was made to assure that the programming techniques utilized would be compatible with a wide variety of computers. Minimal effort should be required to convert the program for use on other computers having a FORTRAN compiler.

The ICON algorithm, like many branch-and-bound algorithms, requires substantial amounts of computer storage for most efficient operation. In the CDC 6700 computer system, the availability of a random access mass storage device fulfills this requirement. The CDC 6700 system subroutines which are required in order to utilize this capability are described in this report. Other computers possess similar capabilities to which the computer program can be readily adapted.

Appendix A provides the general flow schematics on which the computer program is based. Appendix B gives the definitions of parameters and arrays utilized in the program. Aspects of programming

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technique are discussed in Appendices C and D. Appendix C deals with the use of mass storage for the branch-and-bound list while Appendix D deals with the representation and solution of subprograms. The subroutines which comprise the ICON algorithm as well as the system subroutines which are used by the algorithm are described in Appendix E. Finally, Appendix F provides a listing of the computer code.

APPENDIX A

FLOW SCHEMATICS

The general flow schematics for the ICON branch-and-bound algorithm are presented in this appendix. Figure 1 shows the basic sequence of steps which are performed when Method 1 is used, and Figure 2 shows the sequence when Method 2 is used. Methods 1 and 2 are discussed in Volume 1.

The general flow schematics shown in Figures 1 and 2 agree exactly for phase 2 of the branch-and-bound algorithm. The schematic of Figure 1 can be regarded as being embedded in the schematic of Figure 2 if the test "Phase = 1?" in boxes 6, 18 and 28 of Figure 2 is replaced by the test "Phase = 1 and the variable best upper bound method is in use?" With this replacement, Figure 2 represents a general flow schematic for the computer program implementing the ICON algorithm.

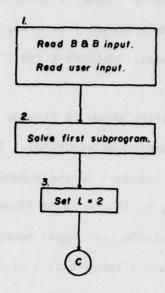


FIGURE 1

FLOW SCHEMATIC FOR THE ICON BRANCH-AND-BOUND ALGORITHM

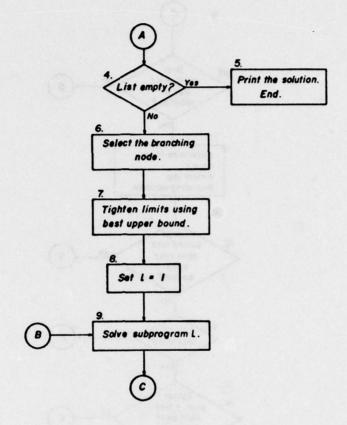


FIGURE 1 (Continued)

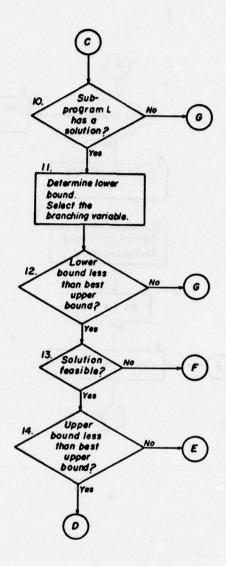


FIGURE 1 (Continued)

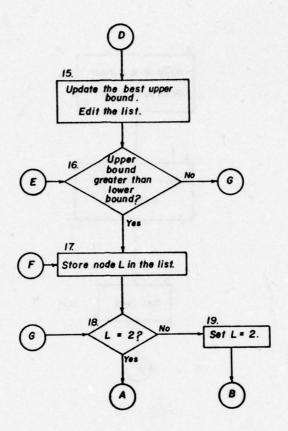


FIGURE 1 (Continued)

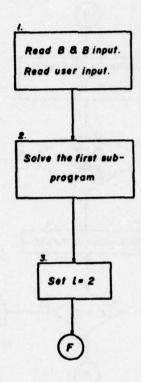


FIGURE 2

FLOW SCHEMATIC FOR THE ICON BRANCH-AND-BOUND ALGORITHM USING THE VARIABLE BEST UPPER BOUND METHOD

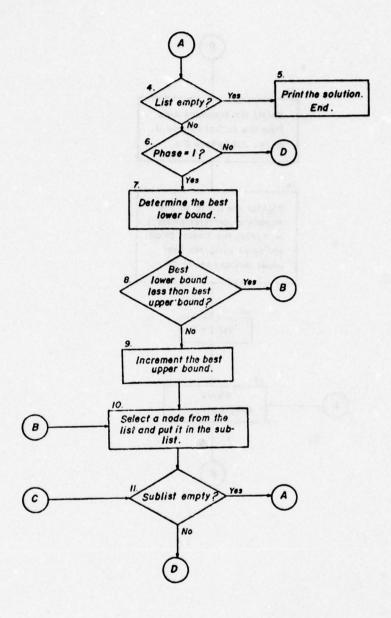


FIGURE 2 (Continued)

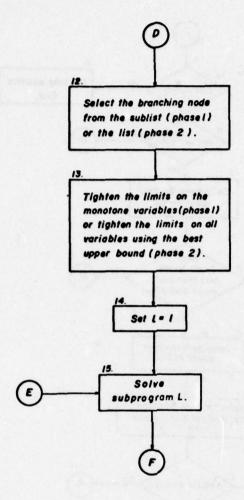


FIGURE 2 (Continued)

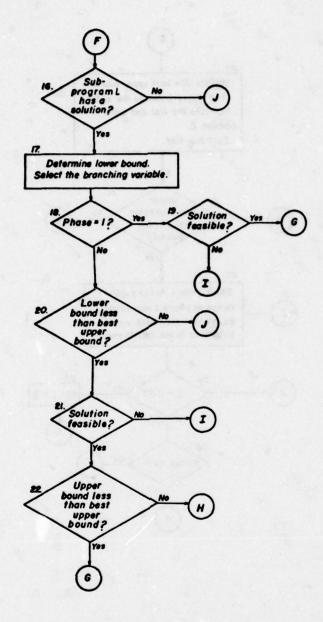


FIGURE 2 (Continued)

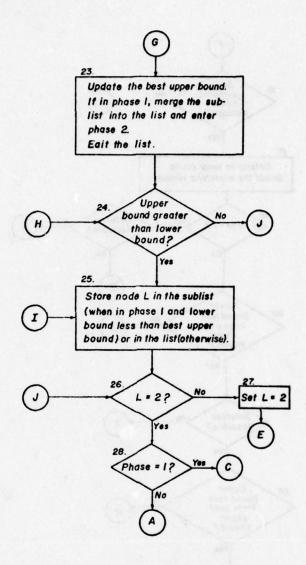


FIGURE 2 (Continued)

APPENDIX B
PARAMETERS AND ARRAYS

The parameters and arrays used in the ICØN branch-and-bound algorithm are described in this appendix. Fixed storage consists of all parameters and two arrays (arrays IMASS2 and IMASS3) which are located in labeled common storage. All other arrays are given variable dimensions, with the actual value of these dimensions being assigned during program execution.

The use of variable dimensions results in the minimization of the core storage required during a computer run, an important factor in the CDC 6700 computer system where the cost of a computer run is proportional to the amount of core storage used. A further benefit from variable dimensioning is the elimination of artificial limits on individual problem parameters (such as the number of variables, N, or the number of constraints, M) which typically result when fixed dimensions are assigned in a computer code. The use of variable dimensioning thus results both in reduced running cost and in program flexibility, where either small or large problems can be solved with the only changes being in the user supplied subroutines.

FIXED STORAGE

Exhibit 1 shows the labeled commons used in the ICØN branch-and-bound algorithm. CØMMØN/PO/ consists of a set of pointers used in conjunction with the variable dimensioning of arrays (parameters NI1 through NI12 and parameters NF1 through NF24) and in conjunction with the branch-and-bound list (parameters NIMS2 and NFMS3). CØMMØN/P1/ consists of the control parameters discussed in Appendix A, Volume 1.

CØMMØN/P2/ consists of those parameters which are used repeatedly in the algorithm. These are:

Variable	Description
EPSI and EPSIM	Tolerances $(10^{-11} \text{ and } -10^{11})$ used to test if a number is zero within roundoff error
BIGN	A large number (10^{100}) used in place of + ∞
BEGTM	The clock time at which the branch-and-bound algorithm commenced the processing of a given program
M1, M2 and M3	The number of less than or equal, equality, and greater than or equal constraints in the program 1
M4	= M2 + M3, the number of artifical variables associated with the program
N1	= $N + (M3 + M1) + (M2 + M3)$, the total number of variables associated with the program including slack, surplus and artifical variables
MP1	= M + 1, the number of basic variables in a one phase linear program, and the position of the linear programming phase 2 objective function among the basic variables

 $^{^{1}\}mathrm{See}$ the discussion of the constraint matrix and right-hand-side vector in Appendix A, Volume 1.

EXHIBIT 1

LABELED COMMON STORAGE

```
COMMON/PO/NI1.NI2.NI3.NI4.NI5.NI6.NI7.NI8.NI9.NI10.NI11.NI12.
               NIMS2, NF1, NF2, NF3, NF4, NF5, NF6, NF7, NF8, NF9, NF10, NF11,
               NF12, NF13, NF14, NF15, NF16, NF17, NF18, NF19, NF20, NF21, NF22,
               NF23.NF24.NFH53
 COMMON/P1/N, M, ITYPE, NSTPAT, NODRL1, NBVRL1, NTITE1, NODRL2, NBVRL2,
NTITE2, MXLIST, LISTOP, ITAPE, IFR, MXITER, MBINV, IOUTPT,
ITRACE, MSTART, TIME1, TOL1, TOL2, PCRUB, ALPHA (10)
COMMON/P2/EPSI, EPSIM, BIGN, BEGTM, M1, M2, M3, M4, N1, MP1, MP2, NM3, NH1H2,
2
               NM1M3.N1P2.NP1.NSUM.NTC.M10
 COMMON/P3/NODNOT, UNOT, I BUBOP, LPHASE, NODRUL, NBVRUL, NTIGHT, NLIST,
               NLISTS, NFEAS, LSTMX, ITRTOT, ITRMAX, BLB, NBRNOD, PBRNOD,
               NBRVAR, NUPDWN, XBRNOD, TBRNOD, NODE, LNODE, Z, BOUNDL, BOUNDU,
2
               TSIG. IFEAS. IBPVR1. TUPON1. XBPVR1. IBRVR2. TUPON2. XBRVR2.
               L10.NITER, NBINV. M7. TPHASE, NPHASE, NM3M7. TALGO. TEOJ
 COMMON/P4/SAVE, KBRAN, X1
 COMMON/P5/IROUND
 COMMON/A0/IMASS2(1001), IMASS3(1001)
```

Variable	Description
MP 2	= M + 2, the number of basic variables in a two phase linear program, and the position of the linear programming phase 1 objective function among the basic variables
NM3	= N + M3, a parameter used in subroutines GETC \emptyset L and \emptyset BJ1
NM1M2	= N - M1 - M2, a parameter used in subroutine GETCØL
NM1M3	= N + M1 + M3, the total number of variables excluding the artificial variables
N1P2	= N1 + 2, the total number of variables plus the linear programming phase 1 and phase 2 objective functions
NP1	= N + 1, a parameter used in subroutines BØX2, BØX15 and ØBJ1
NSUM	The total number of nonzero entries in the constraint matrix $^{\!\!1}$
NTC	The number of constants in the table of constants for the constraint \mathtt{matrix}^1
м10	The position of the objective function (either MP1 or MP2) in the current phase of the linear program

CØMMØN/P3/ consists of those parameters which are required throughout the branch-and-bound algorithm. These are:

Variable	Description
NØDNØT	The node number corresponding to the current best upper bound
UNØT	The current best upper bound

¹See the discussion of the constraint matrix and right-hand-side vector in Appendix A, Volume 1.

Variable	Description
I BUBØP	Indicator for the variable best upper bound method (0 = do not use the method; 1 = use the method)
LPHASE	Current phase of the branch-and-bound algorithm (1 = no feasible point has yet been determined; 2 = a feasible point has been determined and the current best upper bound represents a feasible point)
NØ DRUL	The current node selection rule according to the phase of the branch-and-bound algorithm
NBVRUL	The current branching variable selection rule according to the phase of the branch-and-bound algorithm
NIGHT	The current limit tightening rule according to the phase of the branch-and-bound algorithm
NLIST	Number of nodes currently in the branch-and-bound list
NLISTS	Number of nodes currently in the branch-and-bound sublist
NFEAS	The current total number of nodes for which the corresponding subprogram required complete solution
LSTMX	The current maximum size attained by the branch- and-bound list
ITRTØT	The current total number of linear programming iterations performed
ITRMAX	The current maximum number of linear programming iterations performed along any single branch of the branch-and-bound tree
BLB	The best lower bound
NBRNØD	The node number of the branching node
PBRNØD	The processing order number associated with the branching node

Variable	Description
NBRVAR	The branching variable associated with the branching node
NUPDWN	The direction for continued branching (when the node selection rule is the LIFO rule) for the branching node
XBRNØD	The value of the branching variable in the solution corresponding to the branching node
TBRNØD	The constant associated with the subprogram for the branching node
NØDE	The current node number
LN Ø DE	Indicator for the current node (1 = the lower node emanating from the branching node; 2 = the upper node emanating from the branching node)
Z	The optimal objective function value in a sub-
	program
BØUNDL	The lower bound for the current node
B Ø UN DU	The upper bound for the current node
TSIG	The constant associated with the subprogram for the current node
IFEAS	Indicator as to the feasibility with respect to the master problem of the solution to the current subprogram (0 = not feasible; 1 = feasible)
IBRVR1	Branching variable selection under the first branching variable selection strategy
IUPDN1	The direction for continued branching corresponding to branching variable IBRVR1
XBRVR1	The value of the branching variable IBRVR1
IBRVR2	Branching variable selection under the second branching variable selection strategy
IUPDN 2	The direction for continued branching corresponding to branching variable IBRVR2

Variable	Description
XBRVR2	The value of the branching variable IBRVR2
L10	The number of nonbasic variables associated with the current subprogram tableau
NITER	A counter for the number of linear programming iterations which have been performed to reach the current subprogram tableau
NBINV	A counter, similar to NITER, for the number of linear programming interactions which have been performed since the last basis reinversion
м7	The number of basic variables associated with the current subprogram tableau (either M $+$ 1 or M $+$ 2)
IPHASE	Indicator of the method being applied to solve the current subprogram (1 = one phase method; 2 = two phase method)
NPHASE	The current phase of the method being applied to solve the current subprogram (when IPHASE = 1, NPHASE is not needed and is set to 0; when IPHASE = 2, NPHASE is set to 1 or 2)
им3м7	\approx N + M3 + M7, the number of basic and nonbasic variables associated with the current subprogram tableau
IALGØ	The linear programming algorithm to be applied to move to an optimal tableau for the current subprogram (1 = primal algorithm; 2 = dual simplex algorithm)
IEØJ	Indicator for the tableau resulting from the application of a linear programming algorithm (0 = optimal; 1 = primal infeasible; 2 = primal unbounded; 3 = dual value exceeds the current best upper bound; 4 = maximum number of linear programming iterations exceeded)

COMMON/P4/ consists of three parameters which are used as temporary storage in subroutine BOX15. COMMON/P5/ consists of a single parameter

which is set in subroutine INPUT3 and used in subroutine BØX17. It is used to indicate whether or not the objective function is an integer valued function for a mixed integer linear program. CØMMØN/AO/ consists of two arrays used in conjunction with the branch-and-bound list.

VARIABLE STORAGE

Arrays IF and F are assigned fixed dimensions in program MAIN compatible with the program or programs to be solved. These two arrays are in turn subdivided within the branch-and-bound algorithm into the various integer arrays and floating point arrays required to solve a program. This subdivision varies from program to program depending upon the program structure as specified in the input.

Exhibit 2 shows how the variable dimensioning of arrays is accomplished. Program MAIN transfers control to subroutine ICON, at the same time passing the locations of arrays IF and F together with the corresponding dimensions NI and NF as shown at line 1 of subroutine ICON. These two arrays are dimensioned at line 18 of subroutine ICON. At lines 24-25, control is transferred to subroutine BØX1 which reads the input for the branch-and-bound algorithm and allocates the storage occupied by the arrays IF and F to the various integer and floating point arrays needed in the branch-and-bound algorithm. This allocation is accomplished by developing dimensions ND1 through ND11 for these arrays and by developing pointers NI1 through NI12 for the integer arrays and pointers NF1 through NF24 for the floating point arrays. The subsequent use of these variable dimensioned arrays is exemplified by the call to subroutine BØX7 at line 43 of subroutine ICØN. The first location of the eighth integer array is IF(NI8) and the first location of the thirteenth floating point array is F(NF13). It happens that both of these arrays have the same dimension, ND10. The nomenclature

EXHIBIT 2

EXAMPLE OF VARIABLE DIMENSIONING

	SUBROUTINE ICON	(IF,F,NI,NF)	ICON0001
C	BRANCH-AND-BOUND AL	GORITHM FOR THE INTEGER CONCAVE PROGRAM.	ICON0002
	COMMON/PO/NII.N	12.NI3.NI4.NI5.NI6.NI7.NI8.NI9.NI10.NI11.NI12.	ICONODO3
		NF1.NF2.NF3.NF4.NF5.NF6.NF7.NF8.NF9.NF10.NF11.	ICONDOD4
		NF13.NF14.NF15.NF16.NF17.NF18.NF19.NF20.NF21.NF22.	ICON0005
		NF24. NFMS3	ICON0006
	3 117239	Mr 244 Mr H33	1000000
			· Paring and A
			•
	•		•
	DIMENSION IF (NI	• F (NF)	ICON0018
			•
	The state of the second		•
			•
	100 CALL BOX1 (IF.F.	NI, NF, ND1, ND2, ND3, ND4, ND5, ND6, ND7, ND8, ND9, ND10,	ICON0024
	1 ND11	NDHS2. NDHS3)	ICON0025
	SOUTHWAND TO I NOT		
	CALL BOX7 (TF(N)	18),F(NF13),ND10)	ICON0043
			•
	Alleria and the parties of		
	END		ICON0098
	END		100110030
	SUBROUTINE BOX7	(INUSE, CAPP, ND10)	BOX70001
C	DETERMINE THE BEST		B0X70002
•			
	DIMENSION INUSE	(ND40)	B0X70013
	DIMENSION CAPPO		BDX70014
	DIMENSION CAPPER	40101	90710014
			•
	2:		•
	END		B0X70024

associated with these arrays is modified as shown at line 1 of subroutine BØX7. The labels INUSE and CAPP are mnemonics which reflect
the functions performed by these arrays within the branch-and-bound
algorithm. The arrays are dimensioned at lines 13-14 of subroutine
BØX7 and are manipulated within this subroutine in a manner no different
from that of an array having fixed dimensions.

The dimensions ND1 through ND11 are established in subroutine BØX1 from the control parameters discussed in Appendix A, Volume 1. The values of these dimensions are as follows:

ND1 = N

ND2 = NSUM

ND3 = NTC

ND4 = M + 2

ND5 = N + M3

ND6 = M + 2 + N + M3

ND7 = M + 2

(= 1 if the basis reinversion feature of the program is not used, that is if IFB = MBINV = LISTOP = 0)

ND8 = M + 2

(= 1 if the sensitivity slopes are not needed, that is if NSTRAT = 1, NBVRL1 \geq 3 and NTITE1 = 1, or if NSTRAT = 2, NBVRL1 \geq 3, NBVRL2 \geq 3 and NTITE1 = NTITE2 = 1)

ND9 = N

(=1 if the program to be solved is a mixed integer linear program or a linear program, that is if ITYPE = 1 or 3)

ND10 = MXLIST

ND11 = MXLIST

(= 1 if the LIFO node selection rule is not used, that is if NSTRAT = 1 and NØDRL1 = 1 or if NSTRAT = 2 and NØDRL1 = NØDRL2 = 0).

Array IF is subdivided into the following twelve integer arrays:

Arra	y (Dimension)	Description
1.	NZ(ND1)	The number of nonzero entries in the constraint matrix by column
2.	NP(ND1)	Pointers marking the beginning of each column for arrays IR and IA
3.	IR(ND2)	Row index for a nonzero entry in the con- straint matrix
4.	IA(ND2)	Pointer to the appropriate constant (in the table of constants) for a nonzero entry in the constraint matrix
5.	INT(ND1)	Markers for integer variables (0 = not integer; 1 = first integer variable; 2 = second integer variable; etc.)
6.	ICC(ND1)	Markers for concave variables (0 = not concave; 1 = first concave variable; 2 = second concave variable; etc.)
7.	IS(ND4)	Temporary storage used in the transfer of one column of the constraint matrix (corresponds to the data in array IR)
8.	INUSE(ND10)	Indicator for an entry in the branch-and- bound list (0 = not in use; positive integer = node number of active node in the list; negative integer = node number of active node in the sublist)
9.	NV(ND6)	Temporary storage
10.	IBV(ND4)	Current list of basic variables in a subprogram
11.	NBV(ND5)	Current list of nonbasic variables in a subprogram

Array (Dimension)

Description

12. IUPPER(ND5)

Upper bound indicator for nonbasic variables given in array NBV (0 = nonbasic variable is at lower bound; 1 = nonbasic variable is at upper bound)

Array F is subdivided into the following 24 floating point arrays:

Array (Dimension)		Description				
1.	TC(ND3)	The table of constants for the constraint matrix				
2.	BØRIG(ND4)	The original right-hand-side vector specified in the program input				
3.	RHS(ND4)	The initial right-hand-side vector for a subprogram				
4.	C2(ND1)	The coefficients of the program objective function for variables which enter linearly (i.e., objective function values for concave variables are provided through subroutine GETØBJ)				
5.	C1 (ND5)	Objective function coefficients used in phase 1 of the linear programming solution of the first subprogram				
6.	BI(ND4)	The current values of basic variables in a subprogram				
7.	BN(ND5)	The current values of nonbasic variables in a subprogram				
8.	U(ND6)	The upper limits on the variables in a subprogram				
9.	PJ(ND4)	Temporary storage used (together with array IS) in the transfer of one column of the constraint matrix				
10.	BINV(ND7,ND7)	Temporary storage used to develop the basis inverse when the basis reinversion feature of the program is exercised				
11.	XJ(ND4)	The updated column of the entering variable in the subprogram				

Arra	y (Dimension)	Description
12.	XNØT(ND1)	The current best solution in the branch-and-bound algorithm
13.	CAPP (ND10)	The lower bounds associated with nodes saved in the branch-and-bound list
14.	CAPL(ND11)	The processing order associated with nodes saved in the branch-and-bound list for use in the LIFO node selection rule
15.	SIGMAL(ND6)	The lower limits on the variables for a subprogram
16.	SIGMAU(ND6)	The upper limits on the variables for a subprogram
17.	V(ND6)	Temporary storage (used in conjunction with array NV)
18.	XZ (ND6)	The solution to a subprogram adjusted for lower bound constraints
19.	SO (ND8)	The "left" sensitivity slopes associated with the basic variables in a subprogram solution
20.	S1(ND8)	The "right" sensitivity slopes associated with the basic variables in a subprogram solution
21.	SLØLD(ND6)	The lower limits on the variables for the branching node
22.	SUØLD(ND6)	The upper limits on the variables for the branching node
23.	C2ØLD(ND9)	The coefficients of the program objective function for the branching node
24.	B(ND4,ND4)	The current basis inverse in a subprogram
	The pointers NI1	through NI12 are determined in subroutine BOX1 so

The pointers NI1 through NI12 are determined in subroutine BØX1 so that the elements IF(NI1) through IF(NI12) of array IF correspond to the

first elements of arrays NZ through IUPPER. This is done, in a natural fashion, by setting NI1 = 1, NI2 = NI1 + ND1 where ND1 is the dimension of array NZ, NI3 = NI2 + ND1 where ND1 is the dimension of array NP, and so forth. The pointers NF1 through NF24 are similarly determined so that the elements F(NF1) through F(NF24) of array F correspond to the first elements of arrays TC through B.

APPENDIX C

BRANCH-AND-BOUND LIST

The branch-and-bound list is discussed in this appendix. The list contains a record of the active nodes in the branch-and-bound tree together with the data required to characterize each such node. Associated with the list is the data required by the branching node selection rule or rules to manipulate the list. The record of the active nodes and the branching node selection data are maintained in core storage, while the data required to characterize each node are maintained in random access mass storage.

The items of information which are maintained in core storage are the following:

- (i) The number of nodes in the list (parameter NLIST);
- (ii) The number of nodes in the sublist (parameter NLISTS);
- (iii) The node number for each active node (array INUSE);
- (iv) The lower bound for each active node, used by the priority node selection rule (array CAPP); and
- (v) The processing order for each active node, used by the LIFO node selection rule (array CAPL).

The items of information which are saved in random access mass storage for each active node are the following:

- (i) The lower and upper limits on the variables which serve to characterize a node (arrays SIGMAL and SIGMAU);
- (ii) Branching variable selection data (parameters IBRVR1, IUPDN1, XBRVR1, IBRVR2, IUPDN2, XBRVR2);
- (iii) Limit tightening information (parameter Z, arrays XZ, SO, S1); and
- (iv) The optimal tableau associated with the subprogram (parameters TSIG, L10, NITER, NBINV, M7, IPHASE, NPHASE, NM3M7, arrays IBV, NBV, IUPPER, C2, B).

Depending upon the program solution strategy, the program type, and the branch-and-bound list option, certain of these items need not be saved and are omitted from the list. If only one solution strategy is to be used in the solution of the program (NSTRAT = 1), the data associated with the second solution strategy (parameters IBRVR2, IUPDN2, XBRVR2) are omitted from the list. If limit tightening is not included in the program solution strategy (NSTRAT = 1 and NTITE1 = 1, or NSTRAT = 2 and NTITE1 = NTITE2 = 1), then the data associated only with limit tightening (arrays XZ, SO, S1) are omitted from the list. If the program is a mixed integer linear program (ITYPE = 1), the objective function coefficients (array C2) are the same for all nodes and are omitted from the list. If the branch-and-bound list option indicates that the basis inverse should not be included in the list (LISTOP = 1), then the basis inverse matrix associated with the optimal tableau for a node (array B) is not saved in the list. The basis reinversion feature is then used to regenerate the basis inverse matrix in the event that this node is selected for branching.

The balance of this appendix discusses the mechanics associated with manipulating that portion of the branch-and-bound list which is maintained in random access mass storage. Four integer arrays are associated with the data to be saved in the list. These are:

NV(ND6)

IBV(ND4)

NBV(ND5)

IUPPER (ND5) .

The eleven integer parameters

IBRVR1

IUPDN1

IBRVR2

IUPDN2

L10

NITER

NBINV

M7

IPHASE

NPHASE

NM3M7

are transferred into the <u>last</u> eleven locations of array NV. The integer parameters and arrays to be saved in the list thus occupy

 $NDMS2 = ND4 + 2 \cdot ND5 + 11$

consecutive locations in core storage, all within the basic integer array IF. An auxiliary array IMS, having variable dimension NDMS2, is used to refer to this integer data. The first location of array IMS within the array IF is positioned eleven locations before the first location of array IBV. Setting

NIMS2 = NI10 - 11,

IMS(1) corresponds to IF(NIMS2).

Eight floating point arrays are associated with the data to be saved in the list. These are:

V(ND6)

XZ(ND6)

SO(ND8)

S1 (ND8)

SLØLD(ND6)

SUØLD(ND6)

C2ØLD(ND9)

B(ND4, ND4).

The contents of arrays SIGMAL, SIGMAU and C2 are transferred into the arrays SLØLD, SUØLD and C2ØLD (respectively). The four floating point parameters

Z

TSIG

XBRVR1

XBRVR2

are transferred into the <u>last</u> four locations of array V. The floating point parameters and arrays to be saved in the list thus occupy

 $NDMS3 = (ND4)^2 + 3 \cdot ND6 + 2 \cdot ND8 + ND9 + 4$

consecutive locations in core storage, all within the basic floating point array F. An auxiliary array FMS, is used to refer to this floating point data. The first location of array FMS within the array F is positioned four locations before the first location of array XZ.

Setting

NFMS3 = NF18 - 3,

FMS(1) corresponds to F(NFMS3).

The definitions of the dimensions NDMS2, NDMS3 and the pointers NIMS2, NFMS3 just given correspond to the maximum possible list size. In the event that selected items of data are omitted from the branch-and-bound list, these dimensions and pointers are modified to reflect any such omissions.

Tape units 2 and 3 are the areas of mass storage occupied by the branch-and-bound list. Three CDC 6700 system subroutines are used to establish a random access structure for these areas of mass storage (subroutine OPENMS), to transfer the data for the branching node from mass storage into core storage (subroutine READMS), and to transfer the data for an active node from core storage into mass storage (subroutine WRITMS). Exhibit 3 illustrates the use of these subroutines in the manipulation of the branch-and-bound list. At line 22 of subroutine ICON, a call to subroutine OPENMS establishes the random access structure for tape unit 2. Array IMASS2 is used to store subindices or pointers for 1000 "compartments" located within this area of mass storage. The call to subroutine OPENMS at line 23 of subroutine ICON establishes a similar structure for tape unit 3 using array IMASS3 to store subindices. Subroutine BØX1, called at lines 24-25 of subroutine ICON, sets the values for dimensions NDMS2, NDMS3 and pointers NIMS2, NFMS3 for the particular program being solved. Subroutine BØX12, called at lines 49-51 of subroutine ICON, selects the branching node from the branch-and-bound list (or sublist). The compartment in which

EXHIBIT 3

MANIPULATION OF THE BRANCH-AND-BOUND LIST

```
SURROUTINE ICON (IF.F.NI.NF)

C BRANCH-AND-BOUND ALGORITHM FOR THE INTEGER CONCAVE PROGRAM.

COMMOM/PO/NII.NIZ.NI3.NI4.NI5.NI6.NI7.NI6.NI9.NII0.NIII.NII2.
                                                                                        ICON0001
                                                                                        ICONOGO2
                                                                                        ICONO 00 3
                   NIMS2, NF1, NF2, NF3, NF4, NF5, NF6, NF7, NF8, NF9, NF10, NF11,
                                                                                        ICONO GO 4
                   NF12, NF13, NF14, NF15, NF16, NF17, NF18, NF19, NF20, NF21, NF22, ICON0005
      3
                   NF23, NF24, NFMS3
                                                                                        ICONDO06
       COMMON/AD/IMASS2(1001) + IMASS3(1001)
                                                                                        ICONO017
       DIMENSION IF (NI), F (NF)
                                                                                        ECONGG18
       CALL OPENMS (2.1MASS2.1001.0)
CALL OPENMS (3.1MASS3.1001.0)
                                                                                        ICON0022
                                                                                        ICON0023
  100 CALL BOX1 (IF,F,NI,NF,ND1,ND2,ND3,ND4,ND5,ND6,ND7,ND8,ND9,ND10,
                                                                                        ICON0024
                    ND11.NDMS2.NDMS3)
                                                                                        ICON0025
  160 CALL BOX12 (IF(NI8), IF(NINS2), F(NF4), F(NF15), F(NF14), F(NF15),
                                                                                        I CONOD49
                      F(NF16) . F(NF21) . F(NF22) . F(NF23) . F(NFNS3) . ND1 . ND6 .
                                                                                        ICON0050
                      ND9, ND10, ND11, NDMS2, NDMS3)
      5
                                                                                        ICONDO51
  240 CALL BOX25 (IF(NIB), IF(NIMS2), F(NF4), F(NF13), F(NF14), F(NF15),
                                                                                        ICONO 086
                      F(NF16), F(NF21), F(NF22), F(NF23), F(NFMS3), ND1, ND6,
                                                                                        ICON0087
                      ND9, ND10, ND11, NDMS2, NDMS3)
                                                                                        ICON0088
                                                                                        ICON0098
       SUBROUTINE BOX12 (INUSE, IMS, C2, CAPP, CAPL, SIGNAL, SIGNAU, SLOLD,
                                                                                        BOX10001
                             SUOLD, C2OLD, FMS, ND1, ND6, ND9, ND10, ND11, NDMS2,
                                                                                        30X10002
                                                                                        B0X10003
                             NDMS3)
C SELECT THE BPANCHING NODE FROM THE SUBLIST (PHASE 1) OR THE LIST
                                                                                        BOX 10004
C (PHASE 2).
                                                                                        BOX10005
       DIMENSION INUSE (ND10), IHS (NDHS2)
                                                                                        BOX 10016
       DIMENSION CZ(NO1), CAPP(NO10), CAPL (NO11), SIGHAL (NO6), SIGHAU(ND6),
                                                                                        BOX10017
                   SLOLD (ND6), SUOLD (ND6), C2OLD (ND9), FMS(NDMS3)
                                                                                        30X10018
       CALL READMS (2.IMS.NDMS2.ID)
CALL READMS (3.FMS.NDMS3.ID)
                                                                                        30X10065
                                                                                        BOX 10066
       END
                                                                                        BOX10104
```

EXHIBIT 3 (Continued)

SUBROUTINE BOX25 (INUSE, IMS, C2, CAPP, CAPL, SIGHAL, SIGHAL, SLOLD, SUOLD, C2OLD, FMS, ND1, ND6, NO9, ND10, ND11, NDMS2, NDMS3)	30X20001 B3X20002 B0X20003
C STORE NODE LNODE IN THE SUBLIST (WHEN IN PHASE 1 AND LOWER BOUND LESS	
C THAN BEST UPPER BOUND) OR IN THE LIST (OTHERWISE).	B0X20005
(R. 트립스트) 프리트 레이트 (Refer No. 10 P.	
DIMENSION INUSE(ND10), IMS(NDMS2)	B0X20016
DIMENSION C2(ND1), CAPP(ND10), CAPL(ND11), SIGNAL(ND6), SIGNAU(ND6),	B3X20C17
1 SLOLD (ND6), SUOLD (ND6), C20LD (ND9), FMS (NDMS3)	B0X20018
and the second state of th	
The first contract of the cont	. 17/
360 CALL WRITMS (2.IMS.NDMS2.IO)	B0X20145
CALL WRITHS (3, FMS, NOMS3, IO)	B3X20146
 Johnson J. (1990). Additional South September 1990. 	• 200
END	BDX28195

the data for the branching node is stored (parameter IO) is determined. At line 65 of subroutine BØX12, subroutine READMS is called to transfer the data contained in compartment IO on tape unit 2 into the array IMS in core storage. At line 66 of subroutine BØX12, a similar call of subroutine READMS transfers the data contained in compartment IO on tape unit 3 into the array FMS. Subroutine BØX25, called at lines 86-88 of subroutine ICØN, stores the data for an active node in the branch-and-bound list (or sublist). An available compartment is found (parameter IO) and, at lines 145-146 of subroutine BØX25, two calls to subroutine WRITMS transfer the data contained in arrays IMS and FMS in core storage into compartment IO on tape unit 2 and compartment IO on tape unit 3 (respectively).

APPENDIX D

SUBPROGRAM REPRESENTATION AND SOLUTION

The representation and solution of the subprograms generated by the branch-and-bound algorithm are discussed in this appendix. The data associated with a subprogram (a linear program) are:

- (i) A, the M x N matrix of constraint coefficients;
- (ii) RHS, the right-hand-side vector;
- (iii) C1, the vector of coefficients for the (linear programming) phase 1 objective function;
- (iv) C2, the vector of coefficients for the (linear programming) phase 2 objective function; and
- (v) U, the vector of simple upper bounds on the program variables.

Figure 3 displays this data in the form in which it is used in the computer program.

Specific labeling conventions are adopted for the rows and columns of the linear program. The (M + 2) rows are ordered as follows:

Less than or equal constraints	(M1	rows)
Equality constraints	(M2	rows)
Greater than or equal constraints	(M3	rows)
Phase 2 objective function	(1	row)
Phase 1 objective function	(1	row).

The (N + M + M3 + 2) columns of the linear program are ordered as follows:

Program variables	(N columns)
Surplus variables	(M3 columns)
Slack variables	(M1 columns)
Artificial variables (equality constraints)	(M2 columns)

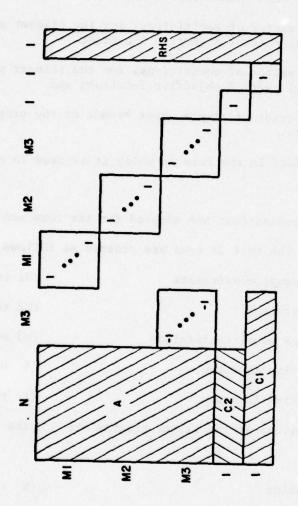


FIGURE 3

SUBPROGRAM REPRESENTATION

Artificial variables (greater than or equal constraints)	(M3	columns)
Phase 2 objective function	(1	column)
Phase 1 objective function	(1	column)
Right-hand-side	(1	column).

The constraint matrix A is represented within the computer program in a form which is commonly used for large linear programs.

The density of nonzero entries in the constraint matrix is frequently low for such programs. Moreover, among the nonzero entries, particular values (such as 1 or - 1) may recur often. Maintaining the entire M x N dimensional constraint matrix in core storage is wasteful for matrices of this type. An alternative means of representing the constraint matrix begins by establishing a table of constants which lists the distinct values which occur in the matrix. For each column of the matrix, the following information is then recorded:

- (i) The number of nonzero entries;
- (ii) For each nonzero entry, the row number in which the entry occurs; and
- (iii) For each nonzero entry, a pointer which indicates the appropriate value in the table of constants.

In the computer program, the array TC corresponds to the table of constants, the array NZ corresponds to the number of nonzero entries by column, the array IR contains the row numbers in which nonzero entries occur, and the array IA contains the corresponding pointers to the table of constants. An auxiliary array NP is defined by the relations NP(1) = 0 and

$$NP(J) = \sum_{I=1}^{J-1} NZ(I)$$

for J=2,N. This array provides a set of pointers for use in conjunction with arrays IR and IA. The data corresponding to the J-th column of the constraint matrix is then stored in the locations NP(J) + 1 through NP(J) + NZ(J) of arrays IR and IA. For extremely large programs, the integer arrays NZ, NP, IR and IA could be maintained in core storage by packing them.

The linear programming code used in this branch-and-bound algorithm utilizes the revised simplex method with simple upper bounds on the variables. This version of the simplex method is discussed in Lasdon (1970) and in Garfinkel and Nemhauser (1972). Both the primal and the dual simplex algorithms are included. The primal algorithm operates either as a one phase method or as a two phase method depending upon the requirements of the program being solved. Associated with this linear programming code is a basis inversion feature which can be used to combat the accumulation of round-off error associated with the simplex pivot operations.

The data associated with the current tableau in a subprogram are:

- (i) IBV, the vector of indices of basic variables;
- (ii) NBV, the vector of indices of nonbasic variables;
- (iii) IUPPER, the vector of indicators of nonbasic variables at upper bound;
- (iv) BI, the vector of values of basic variables;
- (v) BN, the vector of values of nonbasic variables; and

(vi) B, the basis inverse.

These arrays are updated at each simplex iteration. Note that

BI = B(RHS -
$$\sum_{j} U_{j} \cdot P_{j}$$
)

where the summation is taken over all nonbasic variables j which are at upper bound and where P_j denotes the corresponding column in Figure 3. Also, BN can be obtained directly from IUPPER and U. As a consequence, BI and BN need not be saved in the branch-and-bound list.

The initial feasible basis for the first subprogram consists of slack and artificial variables unless the user elects to provide a basis as a part of the branch-and-bound input. A phase 1 objective function is established if there are artificials in the initial basis. The basis is primal feasible if the initial values of the basic variables are nonnegative and do not exceed their upper bounds. In this case, the primal algorithm is applied to solve subprogram 1, using either a one phase method (if there are no artificials in the basis) or a two phase method (otherwise). If the initial basis is not primal feasible, the reduced costs are examined to see if they are nonnegative, in which case the initial basis is dual feasible. In this case, the dual simplex algorithm is applied to solve subprogram 1. In the event that there are artificials in the initial basis, the phase I objective function is treated as a constraint so that the values of these artificials are forced to be zero in the solution. When the solution to subprogram 1 is reached, the optimal basis is tested to see if it contains artificial variables. If no artificials are in this basis, the row and column

corresponding to the phase 1 objective function are deleted from the tableau. If there are artificials remaining in the basis, these necessarily have value zero. However, the phase 1 objective function must be maintained in the tableau as a constraint to assure that these artificials cannot assume positive values in the solutions to subsequent subprograms.

Linear programming sensitivity analysis is applied to solve the subprograms after the first subprogram. This allows the solution of a subprogram to proceed from the optimal tableau associated with the branching node. If the basis inverse is not included in the branch-andbound list, then it is regenerated using the basis inversion feature of the linear programming code. The simple upper bounds U are computed to be the difference between the lower and upper limits SIGMAL and SIGMAU (respectively) on the variables. The initial values BI of the basic variables are computed by adjusting RHS for variables at upper bound and then multiplying by the basis inverse. As a result of the new constraint added for the branching variable and of the tightening of lower and upper limits for the basic variables, this tableau may be primal infeasible. Since the initial feasible point was the optimal solution for the branching node, this tableau is dual feasible. The dual simplex algorithm is applied to generate an optimal solution under the new constraints. The cost coefficients C2 are next updated to reflect any changes made to the lower and upper limits for concave variables. When the cost coefficients change, the reduced costs appearing in the tableau

also change resulting in a tableau which is not in canonical form. The basis inverse and values of the basic variables are modified to reestablish the canonical form of the tableau, which then is primal feasible but not optimal. The primal algorithm is applied to generate an optimal solution for the new cost data. An adequate presentation of the linear programming sensitivity analysis techniques used here may be found in Hillier and Lieberman (1967).

APPENDIX E

SUBROUTINES

The subroutines used in the ICØN branch-and-bound algorithm are discussed in this appendix. The algorithm consists of 29 subroutines. Three of these (MAIN, READIN and GETØBJ are provided by the user for each program to be solved. These are discussed in Appendices B and C of Volume 1. Following is a description of each of the remaining 26 subroutines, indicating the function performed by the subroutine in the algorithm and any notable features of the subroutine. The nomenclature selected for subroutines BØX1 through BØX25 corresponds to the labels which appear in Figure 2, the general flow schematic for the algorithm. Figure 4 shows the number of times one of these subroutines calls or is called by another subroutine.

Subroutine	Description
ICØN	This is the master subroutine which calls the various subroutines in the sequence specified in the general flow schematic for the branch-and-bound algorithm. The initiation of a program solution from previously prepared restart tapes and the preparation of restart tapes when the program time limit is reached are accomplished by calling subroutine RSTART.
BØX1	The branch-and-bound input and the user input are accepted by this subroutine by means of calls to subroutines INPUT1, INPUT2, INPUT3 and READIN. The dimensioning of arrays and the structuring of the branch-and-bound list are done in BØX1.
вфх2	This subroutine initializes the data used in the branch-and-bound algorithm. The initial basis, basis inverse and values of the basic variables are established by a call to subroutine INPUT4. The algorithm to be used to solve the first subprogram is determined by subroutine INPUT5. The first subprogram is then solved.

CALLING SUBROUTINE

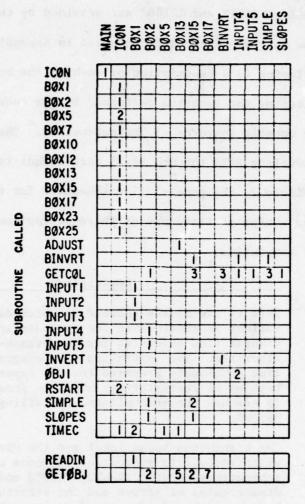


FIGURE 4

CALLS TO ICON SUBROUTINES

Subroutine	Description
вфх5	The solution to the problem at the end of the branch- and-bound computation is printed by this subroutine. It also prints the current best solution in the event that the program time limit is reached and re- start tapes are prepared.
вфх7	This subroutine computes the current best lower bound as required by the variable best upper bound method.
BØX10	This subroutine selects a node from the branch-and- bound list and places it in the sublist as required by the variable best upper bound method.
BØX12	The branching node is selected from the sublist (in phase 1 of the variable best upper bound method) or from the list (in phase 1 of any other solution method and in phase 2). The data for the branching node is read in from random access mass storage (using subroutine READMS) if this data is not already in core. The branching variable selection is adjusted according to the current phase of the branch-and-bound algorithm.
в∕фх13	This subroutine tightens the limits on monotone variables during phase 1 and tightens the limits on all basic variables using the best upper bound during phase 2. The latter function is accomplished by calling the auxiliary subroutine ADJUST.
BØX15	The subprograms associated with the two nodes obtained from the branching node are solved in this subroutine. The tableau associated with the branching node is modified to reflect any new lower and upper limits on the variables. The modified tableau is the starting point for the solution of both subprograms and is saved on tape unit 4 for use in the second subprogram solution. The first subprogram is solved using the dual simplex and primal algorithms, as required. The information on tape unit 4 is read in before the second subprogram is solved.
вфх17	This subroutine determines the lower bound for the node and selects the branching variable. If one of the most noninteger branching variable selection rules (rules 3 or 4) is being used for a mixed

Subrou	t	i	n	e
--------	---	---	---	---

Description

integer linear program (ITYPE = 1), or if the conventional branching variable selection rule (rule 5) is being used for a concave program (ITYPE = 2), the lower bound is taken to be the objective function value Z. If the maxmin or maxmax branching variable selection rules (rules 0, 1 or 2) are being used, the stronger lower bound corresponding to the maxmin penalty is used. If it was determined in subroutine INPUT3 that the objective function is integer valued, then this lower bound is rounded up. When a two strategy method is being used, two branch-variable selections are made.

BØX23

The best upper bound is updated in this subroutine. The branch-and-bound list is edited to delete any nodes for which the lower bound exceeds this new best upper bound. If the algorithm was in phase 1, then phase 2 is entered and the sublist is merged into the list when the variable best upper bound method is being used.

BØX25

The current node is saved in the sublist (in phase 1 of the variable best upper bound method when the lower bound is less than the best upper bound) or in the list (otherwise). The data for the node is placed in random access mass storage (using subroutine WRITMS). In the event that the maximum list size is exceeded, the node having the greatest lower bound is erased from the list to make room for the new node.

ADJUST

This subroutine is called by subroutine BØX13 to adjust the lower and upper limits on a variable using sensitivity analysis information together with the best upper bound.

BINVRT

Basis inversion or reinversion is accomplished by this subroutine. The basis matrix consists of those columns P, from Figure 3 for the basic variables j (specified in array IBV). The corresponding right-hand-side vector is

RHS - $\sum_{j} U_{j} \cdot P_{j}$

S	u	b	r	0	u	t	i	n	e
_	•	_	•	·	-	•	_		•

Description

where the summation is taken over all nonbasic variables j which are at upper bound (specified in arrays NBV and IUPPER). Subroutine INVERT is called to determine the basis inverse matrix and the corresponding values of the basic variables.

GETCØL

This subroutine places the J-th column from the tableau shown in Figure 3 into the array PJ which is assumed to have been set to zero prior to calling the subroutine. The number of nonzero entries in the column and indicators as to which entries are nonzero are returned using parameter NZERØS and array IS.

INPUT1

The number of less than or equal, equality, and greater than or equal constraints are read and the parameters in COMMON/P2/ are initialized. From the number of nonzero entries by column (array NZ), the column pointers are developed (array NP).

INPUT2

The arrays IR and IA associated with the constraint matrix representation are read, along with the number of entries in the table of constants (parameter NTC).

INPUT3

The remainder of the data associated with the constraint matrix, the table of constants and the right-hand-side vector, are read. The lower and upper limits on variables are read in when values other than the default values of 0 and \div ∞ (respectively) are desired. The cost data and lists of integer and/or concave variables are read in next. For a mixed integer linear program (ITYPE = 1), a determination is made if the objective function is integer valued. This information is used in subroutine BØX17 to round lower bounds on the nodes.

INPUT4

Called by subroutine BØX2, this subroutine establishes the initial basis, basis inverse and right-hand-side for the first subprogram. If the initial feasible basis is a part of the program input (IFB = 1 on the first control card), then this basis is read in and the basis inversion feature is used to establish the corresponding basis inverse and right-hand-side. Otherwise, the initial feasible basis consists of slack and arti-

Subroutine

Description

ficial variables with the basis inverse being an identity matrix and the initial right-hand-side agrees with the input right-hand-side vector. In either case, if there are artificals in the initial basis, subroutine ØBJl is called to establish the phase 1 objective function.

INPUT5

This subroutine selects the linear programming algorithm (primal or dual simplex) to be used to solve the first subprogram. The initial basis is tested for primal feasibility (nonnegative right-hand-side) and, if it is primal feasible, the primal algorithm is selected. If the initial basis is not primal feasible, it is tested for dual feasibility (nonnegative reduced cost vector) and, if it is dual feasible, the dual simplex algorithm is selected.

INVERT

The Gauss-Jordan method of matrix inversion is used to invert the basis matrix and determine the corresponding vector of values of basic variables. An ill-conditioned basis matrix, if encountered, results in the termination of computations.

ØBJ1

This subroutine computes and stores the (linear programming) phase 1 objective function associated with the tableau for the first subprogram in its canonical form.

RSTART

The manipulation of job restart tapes (tape units 7 through 10) is done in this subroutine.

If a job is to commence from previously prepared restart tapes (indicated by the setting MSTART = 1 on the second control card), subroutine ICØN calls subroutine RSTART with IENTRY = 0. Tape units 7 and 8 are read, restoring the branch-and-bound list, labeled commons and variable dimensioned arrays to their condition at the time computations were last terminated. In subroutine ICØN, the flow of the branch-and-bound computation is then reentered at the point where computations were terminated.

The determination that job restart tapes are to be created is made in subroutine ICON when the elapsed execution time exceeds the input maximum execution

time (parameter TIME1 on the third control card). The current values of labeled commons (COMMON/P2/, /P3/ and /P4/) and variable dimensioned arrays are saved on tape unit 9. The branch-and-bound list together with intermediate data on tape unit 4 (if any) are saved on tape unit 10. Note that the data saved on tape unit 9 corresponds to the data read from tape unit 7 on a subsequent restart run. Similarly, tape unit 10 corresponds to tape unit 8.

SIMPLE

This subroutine contains the primal and dual simplex algorithms. Basis reinversion is used as a technique for suppressing round-off error in the simplex computations. The frequency of basis reinversion is specified by parameter MBINV on the first control card. In the primal algorithm, the entering variable is taken as the first nonbasic variable encountered having negative reduced cost. As compared with the usual rule in which all reduced costs are computed with the entering variable corresponding to the minimum reduced cost, this frequently results in less total computation in reaching the optimum. A common pivot logic is used for both the primal and dual simplex algorithms. Note that the phase 1 objective function is deleted when no artificials remain in the basis.

The computations in this subroutine can terminate when any one of the following determinations is made:

- (i) The current solution is optimal;
- (ii) The primal program is infeasible;
- (iii) The primal program is unbounded; or
- (iv) The dual value exceeds the best upper bound (for the dual simplex algorithm).

Unboundedness of the primal program is impossible since the lower and upper bounds define a compact set; however, this form of termination can occur due to the accumulation of round-off errors.

Because the dual value in the dual simplex algorithm is monotone nondecreasing, comparison against the

Subroutine	Description
	best upper bound is a useful way of saving unnecessary computation.
SLØPES	This subroutine computes the sensitivity analysis slopes which are required by the branch-and-bound algorithm for penalty analyses. These are computed from the optimal tableau using the dual simplex entering variable selection criteria.
TIMEC	A printout of the elapsed job execution time is obtained by calling this subroutine.

There are six CDC 6700 system subroutines which are used in conjunction with the ICØN algorithm. Only three of these (ØPENMS, READMS and WRITMS) are nonstandard. These are described in Appendix C. Figure 5 shows the number of times each system routine is called by some subroutine in the algorithm.

CALLING SUBROUTINE

MAIN ICON BOXI BOXI2 BOXI2 INVERT RSTART

ØPENMS READMS WRITMS SECOND EOF EXIT

SUBROUTINE CALLED

2 2 2 2 1 1 1 1 1 1 1 1 1

FIGURE 5
CALLS TO SYSTEM SUBROUTINES

APPENDIX F
LISTING OF THE ICON ALGORITHM

This appendix presents a listing of the 26 basic subroutines which comprise the ICØN branch-and-bound algorithm. Not shown in Exhibit 4 are the three user provided subroutines (MAIN, READIN and GETØBJ) discussed in Appendix B, Volume 1.

EXHIBIT 4

LISTING OF THE ICON ALGORITHM

```
SUBROUTINE ICON (1F.F.NI.NF)
C BRANCH-AND-BOUNE ALGORITHM FOR THE INTEGER CONCAVE PROGRAM.
                                                                                        ICONSOS2
       COMMON/PC/NI1, NI2, NI3, NI4, NI5, NI6, NI7, NI8, NI9, NI1C, NI11, NI12,
                                                                                        ICONOG03
                   NIMS2, NF1, NF2, NF3, NF4, NF5, NF6, NF7, NF8, NF9, NF10, NF11,
                                                                                        ICONODD4
                   NF12, NF13, NF14, NF 15, NF1 (, NF17, NF18, NF 19, NF20, NF21, NF22,
                                                                                        ICONDO05
                   NF23, NF24, NFHS3
                                                                                        ICONDO06
       COMMON/P1/N, M, ITYPE, NSTRAT, NOCRL1 , NOVRL1, NTITE1, NOORL2, NOVRL2,
                                                                                        ICONDOD7
                   NTITE2, MXLIST, LISTOP, ITAPE, IFB, MXITER, MBINV, TOUTPT,
                                                                                        ICONDOD8
                   ITRACE, HSTART, TIME1, TOL1, TOL2, PCBUB, ALPHA(10)
                                                                                        ICONDOD9
      2
       COMMON/P2/EPSI, EPSIM, BIGN, BEGTH, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2, ICONOC10
                   NH1H3, N1P2, NP1, NSUM, NTC, H10
                                                                                        ICON0011
       COMMON/P3/NCDNOT, LNOT, IBUBOP, LPHASE, NODRUL, NBVRUL, NTIGHT, NLIST,
                                                                                        ICON0012
                   NLISTS, NFEAS, LSTMX, ITRT (T, ITRMA), åLB, NBRNOD, PBR NOD, NBRVÅR, NUPDWN, XBR NOD, TBRNOD, NODE, LNODE, Z, BOUNDL, BCUNDU,
                                                                                        ICONDC13
                                                                                        ICONOC14
                   TSIG, IF EAS, IBRVR1, IUPCN1, XBRVR1, IBRVR2, IUPDN2, XBRVR2,
                                                                                        ICONDO15
                    L10, NITER, NBINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IECJ
                                                                                        ICONOC16
       COMMON/A0/IMASS2(1001), IMASS3(1001)
                                                                                        ICON0C17
       DIMENSION IF (NI), F(NF)
                                                                                        ICONDO18
       EPSI=1.0E-11
                                                                                        ICONDG19
       EPSI H=-EPSI
                                                                                        ICONDDZD
       BIGN=1.0E+100
                                                                                        ICON0021
       CALL OPENMS (2,IM4SS2,1001,0)
CALL OPENMS (3,IM4SS3,1001,0)
                                                                                        ICONOC22
                                                                                        ICON0C23
  100 CALL 80X1 (IF,F,NI, NF,ND1,ND2,ND3,ND4,ND5,ND6,ND7,ND8,ND9,ND10,
                                                                                        ICONDO24
                    ND11,NEMS2,NDMS3)
                                                                                        ICONDG25
       IF (MSTART .EQ. 0) GOTO110
                                                                                        ICON0026
       CALL RSTART (IF, IF (NI8), IF (NI10), F (NI11), IF (NI12), IF (NIMS2),
                                                                                        ICON0027
                       F, F(NF6), F(NF7), F(NF24), F(NFMS3), NI, NF, ND4, ND5,
                                                                                        ICONDD28
     2
                       ND10, NCMS2, NDMS3, 0)
                                                                                        ICON0029
       G0T0170
                                                                                        ICON0030
  110 CALL BOX2 (IF(NI1), IF(NI2), IF(NI3), IF(NI4), IF(NI5), IF(NI6), IF(NI7), IF(NI8), IF(NI9), IF(NI10), IF(NI11), IF(NI12),
                                                                                        ICONDC31
                                                                                        ICON0032
     2
                    F(NF1), F(NF2), F(NF3), F(NF4), F(NF5), F(NF6), F(NF7),
                                                                                        TCONDO33
     3
                    F(NF8), F(NF9), F(NF10), F(NF11), F(NF12), F(NF15), F(NF16),
                                                                                        ICONOG34
                    F (NF17), F (NF18), F (NF19), F (NF20), F (NF24), ND1, ND2, ND3,
                                                                                        ICON9G35
                    NO4, NO5, NO6, NO7, NO8, NO 10)
                                                                                        ICONDO36
       LNODE=2
                                                                                        ICONDO37
       GOTO190
                                                                                        ICONDO38
  120 IF (NLIST.NE. 0) GOT 0130
                                                                                        ICONDO39
       CALL 80X5 (IF(NI8), F(NF12), F(NF13), F(NF14), ND1, ND10, ND11, 0)
                                                                                        ICON0040
       GOTO100
                                                                                        ICON0041
  130 IF (IBUBOP.EQ.C) GOTO160
                                                                                        ICONDC42
       CALL BOX7 (IF(NIB), F(NF13), NO10)
                                                                                        ICONOC43
       IF (BLB.LT.UNOT) GO TO 140
                                                                                        ICOND044
       UNOT=BLB + PCBUB
                                                                                        ICONDG45
       IF (IOUTPT.NE. U) WRITE(6,1000) UNOT
                                                                                        I CONDC 46
  140 CALL 80X10 (IF(KI8), F(NF13), F(NF14), ND10, ND11)
                                                                                        ICON3047
  150 IF (ALISTS .EQ . 6) 60 TO 120
                                                                                        ICONOC48
  160 CALL BOX12 (IF(N18), IF(NIMS2), F(NF4), F(NF13), F(NF14), F(NF15), F(NF16), F(NF21), F(NF22), F(NF23), F(NFMS3), ND1, ND6,
                                                                                        ICONDU49
                                                                                        ICONOG50
                      ND9, ND10, ND11, NDMS2, NDMS3)
                                                                                        ICON0051
       CALL 80X13 (IF(FIS), IF(NI6), IF(NI10), F(NF4), F(NF15), F(NF16),
                                                                                        ICONOC52
                      F(NF18), F(NF19), F(NF20), F(NF21), F(NF22), ND1, ND4, ND6,
                                                                                        ICONOG53
```

EXHIBIT 4 (Continued)

```
ICONOC54
     LNODE=1
                                                                               ICON0055
                                                                               ICONO056
170 CALL SECOND (TIME2)
     IF (TIME2.LT. BEGTM+TIME1) GOTO180
                                                                               TCONDOS7
     CALL BOX5 (IF(N18), F(NF12), F(NF13), F(NF14), ND1, NU10, ND11, 1)
                                                                               ICONOC58
     CALL RSTART (IF, IF(N18), IF(NI10), IF(NI11), IF(NI12), IF(NIMS2),
                                                                               ICOND059
                   F,F(NF6),F(NF7),F(NF24),F(NFMS3),NI,NF,ND4,ND5,
                                                                               ICONOC60
    2
                   NO10, NOMS2, NEMS3, 1)
                                                                               ICONDC61
     GOT0100
                                                                               TCONDC62
                                                                               ICON0063
 180 CALL BOX15 (IF(NI1), IF(NI2), IF(NI 2), IF(NI4), IF(NI5), IF(NI6),
                   IF(NI7), IF(NI9), IF(NI10), IF(NI11), IF(NI12), F(NF1),
                                                                               ICONOC64
                   F(NF2), F(NF3), F(NF4), F(NF5), F(NF6), F(NF7), F(NF8),
                                                                               ICONOC65
    3
                   F(NF9), F(NF10), F(NF11), F(NF15), F(NF16), F(NF17),
                                                                               ICON3066
                  F(NF18), F(NF19), F(NF20), F(NF21), F(NF23), F(NF24), ND1, ND2, ND3, NC4, ND5, NC6, ND7, ND8, ND9)
                                                                               ICONDO67
                                                                               ICONOC68
                                                                               ICONOC69
 190 IF (IEOJ.NE. 0)GOTO250
     CALL BOX17 (IF(NIS), IF(NI6), IF(NI10), F(NF4), F(NF15), F(NF16),
                                                                               ICONO[70
                  F(NF18), F(NF19), F(NF20), ND1, ND4, ND6, NC8)
                                                                               ICON0071
     IF (IBUBOP.EQ.1)GOTO210
                                                                               ICON0672
     IF (BOUNDL .LT. (1.0-TOL1) *UNOT) GOTO 200
                                                                               ICONDO73
     IF (10UTPT . EQ. 0) GO TO 250
                                                                               ICON0074
                                                                               ICONOG75
     WRITE(6,1001)
                                                                               ICONOC76
     GOTO250
 200 IF (IFEAS.EQ. C)GOTO240
                                                                               ICON9077
     IF (BOUNDU.GE.UNOT )GOTO230
                                                                               ICONDG78
                                                                               ICONOC79
     G0T0220
210 1F (IFEAS. EQ. 0) GOT (240
                                                                               ICONO080
220 CALL BOX23 (IF(NI8), F(NF12), F(NF13), F(NF18), ND1, ND6, ND10)
                                                                               ICONOC81
 230 IF (BOUNDU-BOUNDL.GT.TOL1 * ABS (BOUN [U)) GOTG240
                                                                               TCONDG82
     IF (IOUTPT.EQ.O .OR. ITYPE.EQ. 11GO TO 250
                                                                               ICON0083
                                                                               ICONDO84
     WRITE(6,1002)
     GOT0250
                                                                               ICONDO85
240 CALL 80X25 (IF(NI8), IF(NIKS2), F(NF4), F(NF13), F(NF14), F(NF15),
                                                                               ICON0086
                  F(NF16), F(NF21), F(NF22), F(NF23), F(NFMS3), ND1, ND6,
                                                                               ICONDU87
                  ND9, ND10, ND11, N GM 52, N DM 53)
                                                                               ICON0088
250 IF (IOUTPT.NE.C) CALL TIMEC
                                                                               ICON0090
     IF (LNODE.NE.2) GCTU260
     IF (IBUBOP.EQ.1) GO TO 150
                                                                               ICONDO91
     GOT0120
                                                                               ICONOC92
 260 LNODE=2
                                                                               ICON0093
                                                                              ICON0094
     GOTO170
1000 FORMAT (31HOTHE PHASE 1 BEST UPPER BOUND =, E15.6)
                                                                               TCOND C95
1011 FORMAT (46HOTHE LOVER BOUND EXCEEDS THE BEST UPPER BOUND.)
                                                                               ICONOC96
1002 FORMAT (38HOTHE LONER AND UPPER BOUNDS ARE EQUAL.)
                                                                               ICON0097
                                                                              ICONDE 98
```

EXHIBIT 4 (Continued)

```
SUBROUTINE BOX1 (IF,F,NI,NF,ND1,N(2,ND3,ND4,ND5,ND6,ND7,ND8,ND9,
                                                                                  BOX10CG1
                          ND10, ND11, NDMS2, NDMS3)
                                                                                  BOX10002
C READ ERANCH-AND-BOUND INPUT. READ USER INPUT.
                                                                                   BOX10C03
       COMMON/PO/NI1,NI2,NI3,NI4,NI5,NI6,NI7,NI8,NI9,NI10,NI11,NI12,
                                                                                  BOX10004
                  NIMS2, NF1, NF2, NF3, NF4, NF5, NF6, NF7, NF8, NF9, NF10, NF11
                                                                                   80X10005
                  NF12, NF13, NF14, NF15, NF16, NF17, NF18, NF19, NF20, NF21, NF22,
                                                                                  BOX10006
                  NF23, NF24, NFMS3
                                                                                  BOX10007
                                                                                  BOX10008
       COMMON/P1/N, M, I TYPE, NSTRAT, NOCRL1, NBVRL1, NTITE1, NCORL2, NBVRL2,
                  NTITE2, MXLIST, LISTOP, ITAPE, IFB, MXITER, MBINV, IOUTPT,
                                                                                  BOX10009
                  ITRACE, MSTART, TIME1, TOL1, TOL2, PCBUB, ALPHA(10)
                                                                                  BOX10015
     2
       COMMON/P2/EPSI, EPSIM, dIGN, BEGTM, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2, BOX10011
                  NH1M3,N1P2,NP1,NSUM,NTC,M10
                                                                                  BOX10C12
       COMMON/P3/NODNOT, UNOT, IBUBOP, LPFASE, NODRUL, NBVRUL, NTIGHT, NLIST,
                                                                                  BOX10013
                  NLISTS, NFEAS, LSTMX, ITRT CT, ITRMAX, BLB, NBRNOD, PBRNOC.
                                                                                  BOX10014
                  NBRVAR, NUPDWN, XBR NOD, T BRNOD, NODE, LNODE, Z, BOUNDL, BOUNDU,
                                                                                  BOX10015
     3
                  TSIG, IFEAS, IBRVR1, IUPON1, XBRVR1, IBRVR2, IUFON2, XBRVR2,
                                                                                  BOX10016
                  L10, NITER, NBINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IECJ
                                                                                  80X10C17
       DIMENSION IF (NI) , F (NF)
                                                                                  BOX10018
       CALL SECOND (BEGTM)
                                                                                  BOX13619
                                                                                   BOX10026
C READ THE CONTROL PARAMETERS.
       READ (5, 1000 )N, M, ITYPE, NSTRAT, NODRL1, NBVRL1, NTITE1, NODRL2,
                                                                                  BOX10021
                    NUVRL2, ATITE2, MXLIST, LISTOP, ITAPE, IFB, MXITER,
                                                                                  BOX10C22
                                                                                  80×10023
     2
                    MBINV
       IF (EOF (5) .NE. D. C) CALL EXIT
                                                                                   BOX10024
       IF (N.LE.D) CALL EXIT
                                                                                  BOX10025
       READ (5, 1000) IOUTPT, ITRACE, MSTART
                                                                                  B0X10026
       IF (MXLIST.EQ.C) MXLIST=1000
                                                                                  BOX10027
       IF (MXLIST.GT.1000) MXLIST=1000
                                                                                  BOX10028
       IF (ITAPE.EQ. C) ITA FE=5
                                                                                  BOX10029
       IF ( MXITER. EQ. C) MXITER=1000
                                                                                  BOX10030
       INDEX=0
                                                                                  BOX10031
       IF (FBINV.EQ.O .AND. IFB.EQ.O .AND. LISTOP.EQ. 0) INDEX=1
                                                                                  BOX10032
       READ (5, 1001) TIME1, TOL1, TOL2, UNOT, FCBUB
                                                                                  BOX10L33
       IF (TIME 1. EQ. 0. G) T IME1=180.
                                                                                  BOX10034
       IF (TOL1.EC.O.C) TOL1 =EPSI
                                                                                  BOX10035
       IF (TOL2.EQ. 0.0) TOL2=EPSI
                                                                                  BOX10036
       IF (UNOT.EQ.O.O .OR. PCBUB.NE.O.O) UNOT=BIGN
                                                                                  BOX10037
       IBUBOP=0
                                                                                  BOX10038
       IF (PCBUB. NE. 0.0) IBUBOP=1
                                                                                  BOX10039
       READ (5, 1002) ALPHA
                                                                                  BOX10040
       WRITE(6,1003)N, M, ITYPE, NSTRAT, NODRL1, NBVRL1, NTITE1, NODRL2,
                                                                                  BOX10041
                     NBVRL2, NTITE2, MXL IST, LISTOP, ITAPE, IFB, MXITER,
                                                                                  BOX10042
                     HBINV, IOUTPT, ITRACE, PSTART
                                                                                   BOX10043
       WRITE(6,1004)TIME1, TOL1, TOL2, UNOT, PCBUB
                                                                                  BOX10844
       WRITE(6,1005)ALPHA
                                                                                  BOX10045
       IF (ITRACE.GE.1) WRITE(6,1009)
                                                                                  BOX10046
       ND1=N
                                                                                  BOX10047
       NI 1=1
                                                                                  BOX10048
       NI2=NI1 + ND1
                                                                                  BOX10049
       NI3=NI2 + NE1
                                                                                   BOX10050
C READ THE NUMBER OF CONSTRAINTS, THE NUMBER OF NONZERO ENTRIES IN THE C CONSTRAINT MATRIX (BY CCLUMN), AND DEVELOP THE COLUMN POINTERS.
                                                                                  BOX10051
                                                                                  ROX 10052
       CALL INPUTA (IF (NIA), IF (NIA), NOA)
                                                                                  BOX10053
       ND2=NSUM
                                                                                  BOX10054
       NI4=NI3 + ND2
                                                                                  BOX10055
NIS=NI4 + NC2
C READ THE CONSTRAINT MATRIX COLUMN-BY-COLUMN.
                                                                                  BOX10056
                                                                                  BOX10057
```

```
CALL INPUT2 (IF(NI1), IF(NI2), IF(NI3), IF(NI4), NO1, NO2)
                                                                                BOX10056
                                                                                BOX18059
      NO3=NTC
                                                                                BOX10060
      ND4=H + 2
                                                                                BOX10061
      ND5=N + H3
       ND6=N + M3 + M + 2
                                                                                B0X10062
                                                                                BOX 10063
       IF (ND6.LT.11) ND6=11
      NO7=NO4
                                                                                BOX 10064
                                                                                BOX10065
      IF(INDEX.EQ. 1)ND7=1
       ND8=N04
                                                                                BOX10066
      IF(NBVRL1.LE.2 .OR. NTITE1.EQ. 0) GOTO110
                                                                                BOX10067
      IF (NSTRAT.EQ.1) GOTO100
                                                                                BOX10068
                                                                                BOX10069
      IF(NBVRL2.LE.2 .OR. NTITE2.EQ.0) GOTO110
  100 ND9=1
                                                                                BOX10070
  110 ND9=ND1
                                                                                BOX10071
      IF (ITYPE.EQ.1 .OR. ITYPE.EQ.3) NO 9=1
                                                                                BOX 10072
      NO10=MXLIST
                                                                                BOX10073
                                                                                BOX10074
      ND11=ND10
       IF ( NOORL1. EQ. 1) GOTO 130
                                                                                BOX10075
                                                                                BOX10076
      IF (NSTRAT.EQ.1) GOTO120
                                                                                BOX10077
      IF(NOORL2.EQ.1)GOT0130
                                                                                BOX10078
  120 ND11=1
  130 NI6=NI5 + NO1
                                                                                BOX10079
      NI7=NI6 + ND1
NI8=NI7 + ND4
                                                                                BOX10080
                                                                                BOX10081
      NI9=NI8 + ND10
                                                                                BOX10082
      NI10=NI9 + ND6
                                                                                BOX10083
      NI11=NI10 + NO4
                                                                                BOX10084
      NI12=NI11 + NO5
                                                                                BOX10085
      NITOT=NI12 + NO5
                                                                                BOX10086
                                                                                BOX10087
      NF1=1
      NF2=NF1 + NO3
                                                                                BCX10088
      NF3=NF2 + ND4
                                                                                BOX10089
      NF4=NF3 + ND4
                                                                                BOX10090
      NF5=NF4 + ND1
                                                                                BOX10091
      NF6=NF5 + ND5
                                                                                BOX10092
      NF7=NF6 + NO4
NF8=NF7 + NO5
NF9=NF8 + NO6
                                                                                BOX10093
                                                                                BOX10094
                                                                                BOX10095
      NF10=NF9 + ND4
                                                                                BOX10096
      NF11=NF10 + N07*N07
                                                                                BOX10097
      NF12=NF11 + N04
                                                                                BOX10098
      NF13=NF12 + ND1
                                                                                BOX10099
      NF14=NF13 + ND10
                                                                                BOX 10 100
      NF15=NF14 + ND11
                                                                                BOX10101
      NF16=NF15 + NO6
                                                                                BOX10102
      NF17=NF16 + ND6
                                                                                BOX10103
      NF18=NF17 + ND6
                                                                                BOX10104
      NF19=NF18 + ND6
                                                                                BOX10105
                                                                                BOX10106
      NF20=NF19 + ND8
      NF21=NF20 + ND8
                                                                                BOX10107
                                                                                BOX10108
      NF22=NF21 + ND6
      NF23=NF22 + ND6
                                                                                BOX10109
                                                                                BOX10110
      NF24=NF23 + N09
                                                                                BOX10111
      NFTOT=NF24 + ND4*ND4
IF(NI.LT.NITOT .OR. NF.LT.NFTOT) GOTO230
C READ THE TABLE OF CONSTANTS, THE RIGHT-HAND-SIDE, THE LOWER AND
                                                                                BOX10112
                                                                                BOX10113
C UPPER BOUNDS, THE COST DATA, AND THE LISTS OF INTEGER AND CONCAVE
                                                                                BOX18114
```

```
C VARIABLES.
                                                                               BOX10115
      CALL INPUTS (IF(NIS), IF(NIS), IF(NIS), F(NF1), F(NF2), F(NF4),
                                                                               BOX10116
                    F(NF15), F(NF16), F(NF17), NO1, NO3, NO4, ND6)
                                                                               BOX10117
      WRITE(6,1006) NITOT, NFTOT
                                                                               BOX10118
                                                                               BOX10119
C ESTABLISH THE STRUCTURE OF THE BRANCH-AND-BOUND LIST.
      IF (NSTRAT.EQ.2) GO TO140
                                                                               BOX10120
                                                                               BOX10121
      NI MS2=NI 10 - 9
      NDMS2=ND4 + 2*ND5 + 9
                                                                               BOX10122
                                                                               BOX10123
      GOTO150
                                                                               B0X10124
  140 NIMS2=NI10 - 11
      NDMS 2=N04 + 2*N05 + 11
                                                                               BOX10125
  150 NDHS3=2*ND6 + 3
                                                                               B0X10126
      IF (NTITE1.EQ. 0) GO TO 160
                                                                               BOX10127
                                                                               B0X10128
      IF (NSTRAT. EQ. 1) GO TO 170
                                                                               BOX10129
      IF (NTITE2.EQ. 1) G0 10170
  160 NFMS3=NF18 - 3
                                                                               BOX10130
                                                                               BOX10131
      NDMS3=NOMS3 + ND6 + 2*ND8
                                                                               BOX13132
      GOT0180
                                                                               BOX10133
  170 NFMS3=NF21 - 3
  180 IF (NSTRAT.EQ.1) 60 T0190
                                                                               BOX10134
      NFHS3=NFHS3 - 1
                                                                               BOX10135
                                                                               B0X10136
      NOMS3=NOMS3 + 1
                                                                               BOX10137
  19.0 IF (LISTOP.EQ.1) GO TO200
      NDMS3=NUMS3 + N09 + N04*NC4
                                                                               BOX10138
      60T0216
                                                                               BOX10139
                                                                               BOX10140
  200 IF (ITYPE.EQ. 1) GOTO 210
      NOMS3=NOMS3 + NO9
                                                                               BOX13141
  210 NMSTOT=NDMS2 + NDMS3
                                                                               BOX10142
      WRITE(6, 1007) NHSTOT, NOMS2, NOMS3
                                                                               BOX10143
      IF (IT YPE.EQ. 1)GOTG220
                                                                               80X10144
                                                                               BOX10145
C READ USER INPUT.
      CALL READIN
                                                                               BOX10146
                                                                               BOX10147
  220 CALL TIMEC
                                                                               BOX10148
      RETURN
                                                                               BOX10149
  230 WRITE(6,1006)NITOT,NFTOT
      WRITE(6,1008)NI,NF
                                                                               BOX10 150
                                                                               BOX19151
      CALL TIMEC
      CALL EXIT
                                                                               BOX10152
                                                                               BOX10153
      RE TURN
 1600 FORMAT(1615)
                                                                               BOX10154
                                                                               BOX10155
 1601 FORMAT (5E12.0)
 1602 FORMAT(1CA8)
                                                                               B0X10156
 1003 FORMAT (37H1INPUT FOR BRANCH-AND-BOUND ALGORITHM/
                                                                               BOX10157
              21HOINTEGER FARAMETERS =,1617/21X,317)
21HOREAL PARAMETERS =,5615.6)
                                                                               BOX10158
 1004 FORMAT (21HOREAL
                                                                               BOX10159
 1005 FORMAT(21HGPROGRAP IDENTIFIER =, 4 x, 10A8)
                                                                               BOX10160
 1006 FORMAT (44 HOADEQUATE DIMENSIONS FOR ARRAYS IF AND F ARE, 110,
                                                                               BOX10161
              4H AND, I10, 16H (RESPECTIVELY) .)
                                                                               B0x10162
 1007 FORMAT (39HOTHE BRANCH-AND-BOUND LIST CONSISTS OF ,11G,21H LOCATION BOX10163
     1S PER NODE (,11g,25H LOCATIONS ON UNIT 2 AND ,110,22H LOCATIONS ONBOX10164
     2 UNIT 3).)
                                                                               BOX10165
 1608 FORMAT (15HOTHE DIMENSIONS, 110,4H AND, 110, 18H ARE INSUFFICIENT.)
                                                                               BOX10166
                                                                               BOX10167
BOX10168
 1009 FORMAT (10H *****BCX1)
      END
```

```
SUBROUTINE BOX2 (NZ.NP,IR.IA,INT,ICC,IS,INUSE,NV,IBV,NBV,IUPPER, TC,BORIG,RHS,C2,C1,BI,BN,U,PJ,BINV,XJ,XNCT,
                                                                                   BOX20001
                                                                                   B0X20002
                          SIGHAL, SIGHAU, V, X2, S0, S1, B, N01, N02, N03, N04, N05,
     2
                                                                                   BOX20C03
                          ND6, ND7, ND8, ND10)
                                                                                   BOX20004
C SOLVE THE FIRST SUBPROGRAM.
                                                                                   BOX20005
      COMMON/P1/N, H, ITYPE, NSTRAT, NOORL1, NBVRL1, NTITE1, NOORL2, NBVRL2,
                                                                                   B0X20CJ6
                  NTITE2, MXLIST, LISTOP, IT APE, IFB, MXITER, MBINV, IOUTPT,
                                                                                   BOX20007
                  ITRACE, MSTART, TIME1, TOL1, TOL2, PCBUB, ALPHA (10)
                                                                                   B0X20608
      COMMON/P2/EPS1, EPSIH, EIGN, BEGTH, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2, BOX20039
                  NM1H3, N1P2, NP1, NSUM, NTC, M10
     1
                                                                                   BOX20010
      COMMON/P3/NOONOT, UNOT, IBUBOP, PHASE, NOORUL, NBVRUL, NTIGHT, NLIST, NLISTS, NFEAS, LSTMX, ITRT (T, ITRMAX, BLB, NBRNOD, PBRNOD,
                                                                                   B0X23011
                                                                                   B0X20012
                  NBRVAR, NUPDHN, XBRNOD, TBRNOD, NODE, LNODE, Z, EOUNGL, BCUNDU, BOX20013
                  TSIG, IFEAS, IBRVR1, IUP CN1, XBRVR1, IBRVR2, IUPDN2, XBRVR2,
                                                                                   80X29G14
                  L10, NITER, N8INV, M7, IPHASE, NPHASE, NM3M7, IALGO, IECJ
                                                                                   BOX20015
      DIMENSION INT(NC1), ICC(NC1), IS(ND4), INUSE(ND10)
                                                                                   B0X20016
      DIMENSION BCRIG (NE4), RHS (NO4), C2 (NO1), U(NO6), PJ (NC4), XNOT (NO1),
                                                                                   BOX20017
                  SIGHAL (NO6), SIGMAU(ND6), XZ(ND6), SO(ND8), S1(ND8)
                                                                                   B0X20018
      IF (ITRACE.GE.1) WRITE(6, 1007)
                                                                                   B0X20019
C INITIALIZE THE BEST UPPER BOUND AND LIST.
                                                                                   BOX20020
      LPHASE= 1
                                                                                   B0X20021
      G=TONGON
                                                                                   BOX20022
      DO 10 0J=1, N
                                                                                   BOX20023
  100 XNOT (J) =0.0
                                                                                   BOX20024
      NLIST=C
                                                                                   B0X20025
      NLISTS=0
                                                                                   B0X20026
      NFE AS=0
                                                                                   BOX20027
      LSTMX=0
                                                                                   B0X20028
      ITRTOT=0
                                                                                   B0X20029
      ITRMAX=0
                                                                                   BOX20030
      DO110I=1, MXLIST
                                                                                   B0X20031
  110 INUSE(I)=0
                                                                                   BOX20032
      NODRUL=NOCRL1
                                                                                   B0X20033
      NBVRUL=NBVRL1
                                                                                   BOX20034
      NTIGHT=NTITE1
                                                                                   B0X20035
      PBRNOD= 1.0
                                                                                   B0X20036
      NUPOHN=1
                                                                                   B0X20G37
      NODE=1
                                                                                   BOX20038
      NRRNOD=C
                                                                                   BOX20039
      IF (IOUTPT.NE.C) WRITE (6, 1000 INODE, NBRNOD
                                                                                   BOX20040
C ESTABLISH THE UPPER BOUNDS FOR THE FIRST SUBPROGRAM.
                                                                                   B0X20041
      D0120J=1.N1P2
                                                                                   B0x20642
  120 U(J)=SIGMAU(J)-SIGMAL(J)
                                                                                   BOX20043
C ESTABLISH THE COST DATA FOR THE FIRST SUBPRIGRAM.
                                                                                   B0X20044
      TSIG=0.0
                                                                                   BOX20045
      D0150J=1, N
                                                                                   B0X2004E
      K=ICC(J)
                                                                                   BOX20047
      IF (K. EQ.0) GO TO 140
                                                                                   BOX20048
      CALL GETOBJ (K, SIGHAL(J), FO)
TSIG=TSIG + FC
                                                                                   BOX20049
                                                                                   BOX20050
      IF (ABS(U(J)).LE.TOL2)GOTO130
                                                                                   ROX20051
      CALL GETOBJ (K, SIGHAU(J), F1)
                                                                                   BOX20052.
      C2(J)=(F1-F0)/U(.)
                                                                                   B0X20053
      GOTO150
                                                                                   BOX20054
  130 C2(J)=0.0
                                                                                   80X28055
      COTO150
                                                                                   80X28056
  148 TSIG=TSIG + C2(J) *SIGNAL(J)
                                                                                   B0X28857
```

```
150 CONTINUE
                                                                                BOX20058
       IF (LOUTPT .LE.1) GOT 0190
                                                                                BOX20059
       WRITE(6,1001)TSIG
                                                                                BOX20060
       WRITE(6,1002)
                                                                                BOX20061
       00170J=1.N
                                                                                B0X28662
       K=INT(J)
                                                                                BOX20063
       L=ICC(J)
                                                                                BOX20064
       IF (IOUTPT.GE.3) GO TO 160
                                                                                BOX20065
       IF (K.EQ.O .AND. L.EQ. 0) GO TO 170
                                                                                B0X20066
  160 WRITE(6,1003) J, K, L, SIGNAL (J), SIGNAU(J), C2 (J)
                                                                                B0X20067
  170 CONTINUE
                                                                                B0X20068
       IF (IOUTPT.LE.2)GOT0190
                                                                                BOX20069
       IF (NM1M3.EQ. N) GOT 0190
                                                                                B0X20070
       D0180J=NP1,NM1M3
                                                                                BOX20071
  180 WRITE(6,1004)J, SIGNAL(J), SIGNAU(J)
                                                                                B0X20072
  190 CONTINUE
                                                                                B0X20073
C ESTABLISH THE RIGHT-HAND-SIDE FOR THE FIRST SUBPROGRAP.
                                                                                BOX20074
      D0230I=1, MP1
                                                                               BOX20075
  206 RHS(1)=BORIG(1)
                                                                                BOX20076
      IPHASE=1
                                                                                B0X20077
       00230J=1.N
                                                                                B0X20078
      IF (ABS(SIGNAL(J)).LE.EPSI)GOTO230
                                                                                BOX20079
      D0210I=1, MP1
                                                                                B0X20080
  210 PJ(I)=0.0
                                                                                BOX20081
      CALL GETCOL (NZ,NP,IR,IA,IS,TC,RHS,C2,C1,PJ,NO1,ND2,ND3,ND4,ND5,
                                                                               B0X20082
     1
                     J. NZEROS)
                                                                                BOX20083
      DO22011=1,NZEROS
                                                                                BOX 20084
      I=IS(I1)
                                                                                BOX20085
  220 RHS(I)=RHS(I) - PJ(I)+SIGMAL(J)
                                                                               BOX20086
  230 CONTINUE
                                                                                BOX20C87
C ESTABLISH THE INITIAL BASIS, BASIS INVERSE, AND VALUES OF THE BASIC C VARIABLES FOR THE FIRST SUBPROGRAM.
                                                                                BOX20088
                                                                               80X20089
      GALL INPUT4 (NZ,NP,IR,IA,IS,NV.IB\.NBV,IUFPER,TC,BORIG,RHS,C2,C1, BOX20090
                     BI,BN,U,PJ,BINV,B,ND1,ND2,ND3,ND4,ND5,ND6,ND7)
                                                                               BOX20091
C DETERMINE THE APPLICABLE LP ALGORITHM.
                                                                                B0X20092
      CALL INPUTS (NZ,NP,IR,IA,IS,IBV,NBV,IUPPER,TC,RHS,C2,C1,B1,L,PJ,B,B0X20093
                    ND1, ND2, ND3, ND4, ND5, 106)
                                                                               BOX20094
      IF (IALGO.NE. 0) GOTO 240
                                                                                BOX20095
      IEOJ=1
                                                                               BOX20096
      RETURN
                                                                               BOX20097
C SOLVE THE FIRST SUBPREGRAM.
                                                                               B0X20098
  240 CALL SIMPLE (NZ,NP,IR,IA,IS,NV,IBV,NBV,IUPPER,TC,FHS,C2,C1,BI,BN, BOX20099
                    U,PJ,BINV,XJ,V,XZ,B,ND1,ND2,ND3,ND4,ND5,ND6,ND7)
                                                                               BOX20100
      IF (I EOJ.NE. 0) RETURN
                                                                                BOX20101
      NFEAS=NFEAS + 1
                                                                                BOX 20102
C PRINT THE SOLUTION.
                                                                                BOX20103
      Z=Z+TSIG
                                                                               BOX20104
      D0250J=1,N1P2
                                                                                BOX 2010 5
  250 XZ(J)=XZ(J) + SIGMAL(J)
IF(10UTPT.EQ.0)G0T0260
                                                                                BOX20106
                                                                                BOX20107
      NUP=N
                                                                                BOX2010A
      IF (IOUTPT.GE.3) NUP=NM1H3
                                                                               B0X20109
      WRITE (6,1005)2
                                                                                BOX20110
      WRITE(6,1006)(XZ(J),J=1,NUP)
                                                                               B0X20111
  260 IF (NO8. EQ. 1) RETURN
                                                                               BOX20112
IF (NOVRUL.LE.2 .OR. NTIGHT.EQ.8)GOTO280 C INITIALIZE THE SLOPES.
                                                                                BOX20113
                                                                               80X20114
```

SO(1)=0.0 270 S1(1)=0.0 RETURN G DETERMINE THE SLOPES ASSOCIATED HITH THE OPTIMAL OBJECTIVE VALUE. 280 CALL SLOPES (NZ,NP,IR,IA,IS,IBV,NBV,IUPPER,TC,RHS,C2,C1,PJ,XJ,S0,B0X20121 S1,B,ND1,NO2,ND3,ND4,ND5,ND8) RETURN 1000 FORMAT (111,50 (11+*)/6H0NODE ,15/2GH09RANCHED FROM NDDE ,15) 1001 FORMAT (7H0TSIG = ,E15.6) 1002 FORMAT (9HGVARIABLE,4X,3HINT,8X,2HCC,12X,5HLDHER,12X,5HUPPER,13X,B0X20125 1 4HCOST/2X,6HNUMBER,3X,8HVARIABLE,2X,8HVARIABLE,9X,5HLIMIT,B0X20126 2 12X,5HLIMIT,9X,11HCOEFFICIENT/12X,6HNUMBER,4X,6HNUMBER//) 1004 FORMAT (3X,15,23X,E15.6,2X,E15.6) 1005 FORMAT (17HGSOLUTIGN VALUE =,E15.6) 1006 FORMAT (17HGSOLUTIGN VALUE =,E15.6) 1007 FORMAT (10H *****BOX2) END BOX20133	D0270I=1,H7	B0X20115
270 S1(1)=0.0 RETURN C DETERMINE THE SLOPES ASSOCIATED HITH THE OPTIMAL OBJECTIVE VALUE. 80 CALL SLOPES (NZ,NP,IR,IA,IS,IBV,NBV,IUPPER,TC,RHS,C2,C1,PJ,XJ,SJ,BOX20121 S1,B,ND1,NO2,NO3,NO4,ND5,ND8) RETURN 1000 FORMAT (1H1,50 (1H+)/6H0NODE ,15/2GH09RANCHED FROM NODE ,15) 1001 FORMAT (7HJTSIG = ,E15.6) 1002 FORMAT (9HGVARIABLE,4X,3HINT,8X,2HCC,12X,5HLOMER,12X,5HUPPER,13X,BOX20125 1 4HCOST/2X,6HNUMBER,3X,8HVARIABLE,2X,8HVARIABLE,9X,5HLIMIT,BOX20126 12X,5HLIMIT,9X,11HCOEFFICIENT/12X,6HNUMBER,4X,6HNUMBER//) 1004 FORMAT (3X,15,23X,E15.6,2X,E15.6) 1005 FORMAT (17HGVARIABLES =,6E15.6) 1006 FORMAT (17HGVARIABLES =,6E15.6/(17X,6E15.6)) 1007 FORMAT (101H *****BOX2)		
RETURN C DETERMINE THE SLOPES ASSOCIATED HITH THE OPTIMAL OBJECTIVE VALUE. 280 CALL SLOPES (NZ,NP,IR,IA,IS,IBV,NBV,IUPPER,TC,RHS,C2,C1,PJ,XJ,SJ, B0X2J121 S1,8,ND1,NO2,ND3,ND4,ND5,ND8) RETURN 1000 FORMAT (1H1,50 (1H*)/6H DNODE ,15/2G HOBRANCHED FROM NODE ,15) B0X20121 B0X20122 1001 FORMAT (7HJTSIG = ,E15.6) 1002 FORMAT (9HGVARIABLE,4X,3HINT,8X,2HCC,12X,5HLOMER,12X,5HUPPER,13X, B0X20125 1		BOX 2 J 116
C DETERMINE THE SLOPES ASSOCIATED WITH THE OPTIMAL OBJECTIVE VALUE. 280 CALL SLOPES (NZ,NP,IR,IA,IS,IBV,NBV,IUPPER,TC,RHS,C2,C1,PJ,XJ,S0, 80X2J120 1	270 S1(I)=0.0	BOX20117
280 CALL SLOPES (NZ,NP,IR,IA,IS,IBV,NBV,IUPPER,TC,RHS,C2,C1,PJ,XJ,S0, B0X2J121	RETURN	B0X20118
1 S1,8,ND1,NO2,NO3,NO4,NO5,NO8) RETURN 1000 FORMAT (1H1,50 (1H*)/6H0NODE ,15/2GH0BRANCHED FROM NODE ,15) 1001 FORMAT (7H0TSIG = ,615.6) 1002 FORMAT (9HGVARIABLE,4X,3HINT,8X,2HCC,12X,5HL0HER,12X,5HUPPER,13X, 1 4HCOST/2X,6HNUMBER,3X,8HVARIABLE,2X,8HVARIABLE,9X,5HLIHIT, 2 12X,5HLIMIT,9X,11HCOEFFICIENT/12X,6HNUMBER,4X,6HNUMBER//) 1003 FORMAT (3X,15,2(5X,15),3X,3(615.6,2X)) 1004 FORMAT (3X,15,23X,615.6,2X,615.6) 1005 FORMAT (17H0SOLUTION VALUE =,615.6) 1006 FORMAT (17H0VARIABLES =,6615.6/(17X,6615.6)) 1007 FORMAT (10H ******BOX2)	C DETERMINE THE SLOPES ASSOCIATED WITH THE OPTIMAL OBJECTIVE VALUE.	BOX20119
1 S1,8,ND1,NO2,NO3,NO4,NO5,NO8) RETURN 1000 FORMAT (1H1,50 (1H*)/6H0NODE ,15/2GH0BRANCHED FROM NODE ,15) 1001 FORMAT (7H0TSIG = ,615.6) 1002 FORMAT (9HGVARIABLE,4X,3HINT,8X,2HCC,12X,5HL0HER,12X,5HUPPER,13X, 1 4HCOST/2X,6HNUMBER,3X,8HVARIABLE,2X,8HVARIABLE,9X,5HLIHIT, 2 12X,5HLIMIT,9X,11HCOEFFICIENT/12X,6HNUMBER,4X,6HNUMBER//) 1003 FORMAT (3X,15,2(5X,15),3X,3(615.6,2X)) 1004 FORMAT (3X,15,23X,615.6,2X,615.6) 1005 FORMAT (17H0SOLUTION VALUE =,615.6) 1006 FORMAT (17H0VARIABLES =,6615.6/(17X,6615.6)) 1007 FORMAT (10H ******BOX2)	280 CALL SLOPES (NZ,NP,IR,IA,IS,IBV,NBV,IUPPER,TC,RHS,CZ,C1,PJ,XJ,SQ,	80X2J120
1000 FORMAT (1H1,50 (1H+)/6H0NODE ,15/2GH09RANCHED FRON NODE ,15) 1001 FORMAT (7H0TSIG =, £15.6) 1002 FORMAT (9HGVARIABLE, 4X, 3HINT, 8X, 2HCC, 12X, 5HL0HER, 12X, 5HUPPER, 13X, 1		B0X20121
1001 FORMAT (7H)TSIG =,E15.6) 1002 FORMAT (9HCVARIABLE,4X,3HINT,8X,2HCC,12X,5HLOHER,12X,5HUPPER,13X, 1	RETURN	B0X20122
1002 FORMAT (9HGVARIABLE, 4X, 3HINT, 8X, 2HCC, 12X, 5HLOHER, 12X, 5HUPPER, 13X, 1	1000 FORMAT (1H1,50(1H+)/6H3NODE ,15/2GH39RANCHED FROM NODE ,15)	B0X23123
1 4HCOST/2X,6HNUMBER,3X,8HVARIABLE,2X,8HVARIABLE,9X,5HLIMIT, 2 12X,5HLIMIT,9X,11HCOEFFICIENT/12X,6HNUMBER,4X,6HNUMBER//) 1CJJ FORMAT (JX,15,2(5X,15),3X,3(E15.6,2X)) 1004 FORMAT (JX,15,2JX,E15.6),2X,E15.6) 1005 FORMAT (J7HG SOLUTION VALUE =,E15.6) 1006 FORMAT (J7HG VARIABLES =,6E15.6/(17X,6E15.6)) 1007 FORMAT (JH ******BOX2) BOX20128 BOX20139 BOX20130	1001 FORMAT(7HUTSIG =, £15.6)	B0X20124
1 4HCOST/2X,6HNUMBER,3X,8HVARIABLE,2X,8HVARIABLE,9X,5HLIMIT, 2 12X,5HLIMIT,9X,11HCOEFFICIENT/12X,6HNUMBER,4X,6HNUMBER//) 1CJJ FORMAT (JX,15,2(5X,15),3X,3(E15.6,2X)) 1004 FORMAT (JX,15,2JX,E15.6),2X,E15.6) 1005 FORMAT (J7HG SOLUTION VALUE =,E15.6) 1006 FORMAT (J7HG VARIABLES =,6E15.6/(17X,6E15.6)) 1007 FORMAT (JH ******BOX2) BOX20128 BOX20139 BOX20130	1002 FORMAT (9HGVARIABLE, 4X, 3HINT, 8X, 2HCC, 12X, 5HLONER, 12X, 5HUPPER, 13X,	B0X20125
103 FORMAT (3x,15,2(5x,15),3x,3(E15.6,2x)) 1004 FORMAT (3x,15,23x,E15.6,2x,E15.6) 1005 FORMAT (17H0 SOLUTION VALUE =,E15.6) 1006 FORMAT (17H0 VARIABLES =,6E15.6/(17x,6E15.6)) 1007 FORMAT (13H ************************************		B0X20126
1004 FORMAT (3X, 15, 23X, E15.6, 2X, E15.6) 1005 FORMAT (17H0 SOLUTION VALUE =, E15.6) 1006 FORMAT (17H0 VARIABLES =, 6E15.6/(17X, 6E15.6)) 1007 FORMAT (13H ************************************	2 12X,5HLIMIT,9X,11HCOEFFICIENT/12X,6HNUMBER,4X,6HNUMBER//)	BOX20127
1005 FORMAT (17H0 SOLUTION VALUE =, £15.6) 1006 FORMAT (17H0 VARIABLES =, £6£15.6/(17X, £6£15.6)) 1007 FORMAT (13H ******BOX2) BOX20132	1003 FORMAT (3x,15,2 (5x,15),3x,3(E15.6,2x))	B0X20128
1006 FORMAT (17H0 VARIABLES = .6E15.6/(17X,6E15.6)) BOX2J131 1007 FORMAT (13H *****BOX2) BOX2J132	1004 FORMAT (3X, I5, 23X, E15.6, 2X, E15.6)	B0X20129
1006 FORMAT (17H0 VARIABLES = .6E15.6/(17X,6E15.6)) 1007 FORMAT (13H *****BOX2) BOX20132	1005 FORMAT (17HG SOLUTION VALUE =, E15.6)	BOX23130
1007 FORMAT (13H *****BOX2) BOX20132	1006 FORMAT (17H0 VARIABLES =,6E15.6/(17X.6E15.6))	BOX2 131
END BOX20133	1007 FORMAT (13H *****BOX2)	
	END	BOX 20133

```
SUBROUTINE BOX5 (INLSE, XNOT, CAPP, CAPL, NO1, ND10, ND11, IENTRY)
                                                                                  BOX50861
                                                                                  BOX50082
G PRINT THE SOLUTION.
      COMMON/P1/N, M, ITYPE, NSTRAT, NOCRL1, MBVRL1, NTITE1, NOORL2, NBVRL2,
                                                                                  BOX50003
                  NTITE2, MXLIST, LISTOP, IT APE, IF0, MXITER, MBINY, IOUTPT, ITRACE, MSTART, TIME1, TCL1, TOL2, PCBU8, A LPMA (10)
                                                                                  BOX50004
                                                                                  BOX50005
      COMMON/P3/NO CNOT, UNOT, I BUBOP, LPHASE, NODRUL, NBVRUL, NTIGHT, NLIST.
                                                                                  BOX50606
                  NLISTS, NFEAS, LSTMX, ITRT CT, ITRMAX, BLB, NBRNOD, PBRNOD,
                                                                                  B0 X50007
                  NBRYAR, NUPDHN, XBRNOD, TBRNOD, NODE, LNODE, Z, BOUNDL, BCUNDU,
                                                                                  BOX50008
                  TSIG, IFEAS, IBRVR1, IUPON1, XBRVR1, IBRVR2, IUPON2, XBRVR2,
                                                                                  BOX50009
                  L10, NITER, NBINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IEOJ
                                                                                  BOX50010
                                                                                  BOX50011
      DIMENSION INUSE (NC1C)
      DIMENSION XNOT (ND1), CAPP (ND10), CAFL (ND11)
                                                                                  BOX50012
                                                                                  BOX50013
       IF (ITRACE.GE.1) hRITE(6,1017)
C PRINT OUT PROGRAM IDENTIFICATION.
                                                                                  BOX50014
      WRITE (6, 1000)N, M, ITYPE, NSTRAT, NODFL1, NBVRL1, NTITE1, NOORL2,
                                                                                  80X50015
                     NOVEL2, NTITE2, HXLIST, LISTOP, ITAPE, IFB, MXITER,
                                                                                  B0X50016
                      MBINV, IOUTPT, ITRACE, MSTART
                                                                                  BOX50017
      WRITE (6, 1001) TIME 1, TOL1, TOL2, UNOT, PCBUB
                                                                                  BOX50018
                                                                                  80X50019
      WRITE(6, 1002)ALPHA
C PRINT OUT THE SOLUTION OR THE CURRENT BEST SOLUTION.
                                                                                  BOX50020
      IF (IENTRY.EQ.1)GOTO100
                                                                                  BOX50021
                                                                                  B0X50022
       WRITE(6,1003)NODNOT
                                                                                  BOX50023
       REWIND 9
                                                                                  80X50024
       REWIND 10
       WRITE (9) NODNCT
                                                                                  B0X50025
       WRITE (10) NO ENOT
                                                                                  80X50026
                                                                                  BOX50027
      END FILE 9
                                                                                  B0X50028
      END FILE 10
                                                                                  BOX50029
       GOTO113
  100 WRITE(6,1004)NODNOT
                                                                                  BOX50030
  110 WRITE(6,1005)UNCT
WRITE(6,1006)(XNOT(I),I=1,N)
                                                                                  BOX50031
                                                                                  BOX50032
                                                                                  BOX50033
       WRITE(6,1007)NODE
       WRITE(6,1008)NFEAS
                                                                                  BOX50034
       WRITE(6,1009)LSTMX
                                                                                  BOX50035
      WRITE(6,1010)ITRTCT
                                                                                  BOX50036
                                                                                  BOX50037
       WRITE(6,1011)ITRMAX
       IF (IENTRY . NE . 1) GOTO180
                                                                                  BOX50038
C PRINT OUT THE LIST.
                                                                                  BOX50039
                                                                                  BOX50040
      WRITE(6,1012) NLIS 1
       INDEX=0
                                                                                  BOX50041
      IF (NSTRAT.EQ.2)GOTO120
                                                                                  BOX50042
       IF (NOORL1.EQ.1) GO TO 140
                                                                                  BOX50043
                                                                                  BOX50044
       GOT0130
  120 IF (NOORL2.EQ.1) GO TO140
                                                                                  80X50045
                                                                                  BOX50046
       IF (LPHASE.EQ.1 .AND. NODRL1.EQ.1)GOT0140
  130 INDEX=1
                                                                                  BOX50047
      WRITE(6,1013)
                                                                                  BOX50048
       GOT0150
                                                                                  BOX50049
  140 WRITE (6,1014)
                                                                                  BOX50050
                                                                                  BOX50651
  150 00170I=1, MXLIST
       IF (INUSE(I).EQ. C) GCT0170
                                                                                  BOX50052
       IF (INDEX. EQ. 0) GOT (1.0
                                                                                  BOX50053
                                                                                  BOX50654
       WRITE (6,1015) INUSE (I), CAPP(I)
                                                                                  80X50955
       GOTO170
  16G WRITE(6,1016)INUSE(I), CAPP(I), CAPL(I)
                                                                                  BOX50056
  170 CONTINUE
                                                                                  BOX50057
```

180 CALL TIMEC RETURN	80X58858 80X58859
1830 FORMAT(21+1INTEGER PARAMETERS =,1(17/21x, JI7)	BOX50660
1661 FORMAT (21HO REAL PARAMETERS =, 5E15.6)	B0X50061
1002 FORMAT (21HO PROGRAM IDENTIFIER =,4x,10A8)	B0X50062
1603 FORMATIGENOTHE SOLUTION TO THE INTEGER CONCAVE PROGRAM WAS PA	ROVIDEBOX50063
1D dy NODE ,15)	BOX50064
1614 FORMAT (79HOTHE CURRENT BEST SCLUTION TO THE INTEGER CONCAVE F	PROGRABOX50C65
1M MAS PROVIDED BY NODE . 15)	B0X50066
1005 FORMAT(17H0SOLUTION VALUE =, £15.6) 1006 FORMAT(17H0VARIABLES =, 6£15.6/(17x, 6£15.6))	80X50G67 80X50G68
16G7 FORMAT (34HOTHE NUMBER OF NODES EXAMINED WAS . 15)	B0X50069
1608 FORMAT (32H THE NUMBER OF NODES SOLVED WAS .2X.15)	BOX50070
1009 FORMAT (27HOTHE MAXIMUM LIST SIZE WAS ,15)	BOX50C71
1010 FORMAT (54FOTHE TOTAL NUMBER OF SIPPLEX ITERATIONS PERFORMED 1	BOX50072
1011 FORMAT (51H THE MAXIMUM NUMBER PERFORMED ALONG ANY BRANCH HAS	, 80X50074
1 3x,17)	BOX50C75
1012 FORMAT(26HOTHE CURRENT LIST SIZE IS , 15)	B0X50C76
1613 FORMAT(1H0,3X,4HNCUE,9X,5HLOHER/17X,5HBCUND//)	BOX50C77
1014 FORMAT(1HC, 3X, 4HNCDE, 9X, 5HL OHER, 8X, 10HPROCESSING/17X, 5HBOUND,	BOX50078
1 11X, SHORCER//)	80X50079
1615 FORMAT(3X,15,2X,E15.6)	BOX50080
1616 FORMAT(3X,15,2X,E15.6,2X,F11.0)	80X50G81
1017 FORMAT(10H *****BCX5)	B0X50682
END	BOX50083

```
SUBROUTINE BOX7 (INUSE, CAPP, ND10)
C DETERMINE THE BEST LOWER BOUND.
COMMON/P1/N, M, ITY PE, NSTRAT, NOCKL1, NBVRL1, NTITE1, NOCKL2, NB VRL2,
                                                                                                      BOX70001
                                                                                                      BOX70002
                                                                                                      80X73C03
                      N TITE2, MXLIST, LISTOP, IT APE, IF E, MXITER, MEINV, IOUTPT,
                                                                                                      BOX70C04
        ITRACE, MSTART, TIME1, TOL1, TOL2, PCBUB, ALPHA(10) BOX70005
COMMON/PZ/EPSI, EPSIM, BIGN, BEGTM, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2, BOX7006
                      NM1M3,N1P2,NP1,NSUM,NTC,M10
                                                                                                      BOX70007
        COMMON/P3/NODNOT, UNOT, IBUBOP, LPHASE, NODRUL, NBVRUL, NTIGHT, NLIST, NLISTS, NFEAS, LSTMX, ITRT(T, ITRHAX, BLB, NBRNOD, PBRNOD,
                                                                                                      B0X71038
                                                                                                      90X79609
                      NBRVAR, NUPOWN, XERNOD, TBRNOD, NOGE, LNODE, Z. BOUNDL, BCUNDU, BOX70010
                      TSIG, IFEAS, IBRYR1, ILPON1, XBRYR1, IBRYR2, IUFDN2, XBRYR2, L10, NITER, NOINY, M7, IPHASE, NPHASE, NM3M7, IALGO, IECJ
                                                                                                      BOX70011
                                                                                                      BOX70012
        DIMENSION INUSE (NO10)
                                                                                                      BOX73013
        DIMENSION CAPP (ND10)
                                                                                                      BOX70614
        IF (ITRACE.GE. 1) WRITE(6,1000)
                                                                                                      BOX70C15
                                                                                                      BOX79C16
        BL 8= BIGN
        001001=1, MXL IST
                                                                                                      BOX79617
        IF (INUSE(I) . EQ. 3) GOTO100
                                                                                                      B0X79618
        IF (CAPP (I) . GE. 8L8 1GOTO100
                                                                                                      BOX70619
        BLB=CAPP(I)
                                                                                                      BOX70026
  100 CONTINUE
                                                                                                      BOX73621
        RETURN
                                                                                                      B0X73022
 1600 FORMAT (10H ***** BCX7)
                                                                                                      B0X70023
        END
                                                                                                      BOX73624
```

```
SUBROUTINE BOX12 (INUSE, CAPP, CAPL, ND12, ND11)
                                                                                    BOX 10001
C SELECT A NODE FROM THE LIST AND PUT IT IN THE SUBLIST.
                                                                                    BOX10062
      COMMON/P1/N, M, ITYPE, NSTRAT, NODRL1, NBVRL1, NTITE1, NODRL2, NBVRL2, NTITE2, MXLIST, LISTOP, ITAPE, IFB, MXITER, MBINV, IOUTPT,
                                                                                    BOX10063
                                                                                    BOX13-4
     2
                  ITRACE, MSTART, TIME1, TOL 1, TOL 2, PCBUB, ALPHA (10)
                                                                                    BOX10LC5
      COMMON/P3/NODNOT, UNOT, IBUBOP, LPHASE, NODRUL, NBVRUL, NTIGHT, NLIST,
                                                                                    BOX10206
                  NLISTS, NFEAS, LSTMX, ITRTOT, ITRMAX, BLB, NBRNOD, PBRNOD,
                                                                                    BOX13367
     1
     2
                  NBRVAR, NUPDHN , XBRHOD, TBRNOD, NODE , LNODE , Z, BOUNDL , BOUNDU, BOX : 1. 18
                  TSIG, IFEAS, IBRVR1, IUPON1, XBRVR1, IBRVR2, IUPON2, XBRVR2,
     3
                                                                                    BOX16369
                  L10, NITER, NBINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IEOJ
                                                                                    BOX10010
      DIMENSION INUSE (NO10)
                                                                                    BOX10011
      DIMENSION CAPP (ND1), CAPL (ND11)
                                                                                    80X10.12
      IF(ITRACE.GE.1) WRITE(6, 1000)
                                                                                    BOX10013
C SELECT THE NODE.
                                                                                    BOX10014
      PBRNOD=3.0
                                                                                    BOX10015
      DO100I=1, MXLIST
                                                                                    B0X13616
       IF (INUSE (I) .EQ. .) GOTO 100
                                                                                    B0X13017
       IF (CAPP(I).GE. UNOT) GOTO13:
                                                                                    BOX10018
      IF (CAPL(I).LE. PBRNOD) GOTO100
                                                                                    BOX10619
      PBRNOD=CAPL (I)
                                                                                    BOX10020
      IJ=I
                                                                                    B0X10321
  100 CONTINUE
                                                                                    BOX13.22
C PUT IT IN THE SUBLIST.
                                                                                    60X10023
      INUSE (IO) = - INUSE (IO)
                                                                                    B0X10024
       NLISTS=NLISTS+1
                                                                                    BOX10025
       RETURN
                                                                                    B0X16026
 1000 FORMAT (11H ***** BOX10)
                                                                                    BOX10027
      FND
                                                                                    B0X10028
```

```
BOX10001
      SUBROUTINE BOX12 (INUSE, IMS, C2, CA FP, CAPL, SIGHAL, SIGHAU, SLOLD,
                        SUOLO, CZOLO, FMS, NO1, ND6, ND9, ND10, ND11, NDMS2,
                                                                          BOX10632
                        NONS3)
                                                                           BOX10003
C SELECT THE BRANCHING NODE FROM THE SUBLIST (PHASE 1) OR THE LIST
                                                                           BOX10004
C (PHASE 21.
                                                                          BOX10CG5
      GOMM CN/P1/N, M, ITYPE, NSTRAT, NODRL1, NBVRL1, NTITE1, NODRL2, NB VRL2,
                                                                          BOX10006
                NTITE2, MXLIST, LISTOP, ITAPE, IFB, MXITER, HBINY, IOUTPT, ITRACE, MSTART, TIME1, TOL1, TOL2, PCBUB, ALPHA(10)
                                                                           BOX10367
     2
                                                                           80X10036
      COMMON/P2/EPSI, EPSIM, BIGN, BEGTM, M 1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2, 80X10009
                NH1H3, N1P2, NP1, NSUM, NTC, M10
     1
                                                                          BOX10010
      COMMON/P3/NODNOT, UNOT, IBUBOP, LPFASE, NODRUL, NB VRUL, NTIGHT, NLIST,
                                                                          BOX10011
                NLISTS, NFEAS, LSTMX, ITRT (T, ITRMAX, EL 8, NBRNOD, PBRNOD,
                                                                           BOX10612
                NERVAR, NUPDHN, XERNOD, TBRNOD, NODE, LNODE, Z, BOUNDL, BCUNDU, BOX13613
     2
                TSIG, IFEAS, IBRVR1, IUPCN1, XBRVR1, IBRVR2, IUPON2, XBRVR2,
                                                                          30X10C14
                L10, NITER, NJINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IEOJ
                                                                          BOX19015
     DIMENSION INUSE (NO10), IMS (NOMS2)
                                                                          BOX10016
      DIMENSION C2(ND1), CAPP(NO10), CAPL(ND11), SIGMAL(ND6), SIGMAU(ND6),
                                                                          BOX10017
                SLOLD (NC61, SUOL C(ND61, C20LD (ND9), FMS( NDMS3)
                                                                           BOX10618
     1
      IF (ITRACE.GE.1) WRITE(6,1000)
                                                                          BOX10019
      IF (IBUBOP.EQ.C) GOTO110
                                                                          BOX13C2L
                                 C SELECT THE BRANCHING NODE FROM THE SUBLIST.
                                                                          BOX10022
                                                                   ******B0X19023
      PBRNOD=0.0
                                                                          BOX15024
      DO1JOI=1, MXLIST
                                                                          BOX10025
      IF (INUSE(I).GE.C) GOTO100
                                                                          80X 10C 26
      IF (CAPL(I).LE.PBRNOD) GOTO100
                                                                          BOX10027
      PBRNOD=CAPL(I)
                                                                          BOX13028
      NBRNOD=-INUSE(I)
                                                                          BOX10029
      10=1
                                                                          BOX 10030
100 CONTINUE
C DECREMENT THE SUBLIST COUNTER.
                                                                          BOX13631
                                                                          BOX10032
                                                                          BOX10033
      NLISTS=NLISTS-1
      GOT0150
                                                                          BOX10034
*B0X10635
C SELECT THE BRANCHING NODE FROM THE LIST.
                                                                          BOX10036
*B0X10037
  110 IF (NOORUL.EQ.1) GO TO 130
                                                                          BOX10038
C FRICRITY NODE SELECTION RULE.
                                                                          BOX10539
      BLB=BIGN
                                                                          BOX13043
      D0120I=1, MXL IST
                                                                          BOX10941
      IF (INUSE (I) . EQ. C) GOTO120
                                                                          BOX10042
      IF (CAPP(I).GE.BLB)GOT0120
                                                                          BOX10043
      BLB=CAPP(I)
                                                                           30X13C44
      NBRNOD=INUSE(1)
                                                                          BOX10045
      10=I
                                                                          BOX10046
  120 CONTINUE
                                                                          BOX13047
      GOT0150
                                                                          BOX13048
C LIFO NODE SELECTION RULE.
                                                                          BOX10049
  136 PBRN00=0.0
                                                                          BOX10050
      001401=1, MXL IST
                                                                          BOX13051
      IF (INUSE(I).EQ. 8) GOTO140
                                                                          80×10152
      IF (CAPL (I).LE.PBRNOO) GOTO140
                                                                          BOX10053
      PBRNOD=CAPL (I)
                                                                          BOX10054
      NBRNOD= INUSE (I)
                                                                          BOX10055
      10=1
                                                                          BOX 10056
  140 CONTINUE
                                                                          BOX10057
```

```
BOX13058
C DECREMENT THE LIST COUNTER.
                                                                        BOX10059
  150 INUSE(IL)=0
      NLIST=NLIST-1
                                                                         BOX10060
C READ IN THE DATA FOR THE BRANCHING NOIE. BOX10062
      IF (NODE.EQ. NORNCO)GOTO200
                                                                        BOX10064
      CALL READMS (2, IMS, NDMS2, 10)
CALL READMS (3, FMS, NDMS3, 10)
                                                                        BOX10065
                                                                         BOX10066
      IBRVR1=IMS(1)
                                                                        BOX10067
      IUPON1=IMS(2)
                                                                        BOX10668
      L10= IMS (3)
                                                                        BOX10069
      NITER=IMS (4)
                                                                         BOX 10070
      NBINV=IMS (5)
                                                                        BOX10071
                                                                        BOX10072
      M7=IMS(6)
      IPHASE=IMS(7)
                                                                         BOX10073
      NPHASE=IMS(8)
                                                                         BOX 13674
      NM3H7=IMS (9)
                                                                        BOX13675
                                                                        ROX13076
      IF (NSTRAT . EQ . 1) GO 10160
      IBRURZ= IMS(10)
                                                                        BOX15077
      IUPON2=IMS(11)
                                                                        BOX10078
 166 Z=FMS(1)
                                                                        B0X10079
                                                                        80X19983
      TSIG=FMS (2)
      XURVR1=FHS(3)
                                                                        BOX10081
      IF (NSTRAT.EQ. 1) GOT 0170
                                                                        BOX10682
      XBRVR2=FMS(4)
                                                                        80X13683
 176 00180J=1,N1P2
                                                                        80X13084
      SIGMAL(J)=SLOLD(J)
                                                                        BOX10085
  180 SIGMAU(J)=SUOLD(J)
                                                                        BOX1008E
      IF (ITYPE.EQ.11GOTO206
                                                                        BOX13087
      D0190J=1,N
                                                                        BOX10588
  196 C2(J)=C20LD(J)
                                                                        BOX13389
  200 TBRNOO=ISIG
                                                                        BOX13990
C ALJUST THE BRANCHING VARIABLE SELECTION ACCORDING TO THE CURRENT
                                                                        BOX13691
C PHASE OF THE ALGORITHY.
                                                                        BOX13092
      IF INSTRAT . EQ. 1) GU TU 210
                                                                        BOX13693
      IF (LPHASE . EQ . 1) GO TO 219
                                                                        BOX10094
      NBRVAR= IBRVR 2
                                                                        BOX11095
      NUPOWN=IUFON2
                                                                        BOX13096
      XBRNOD=XBRVR2
                                                                        BOX10097
      RETURN
                                                                        BOX100 98
  210 NBRVAR=1BRVR1
                                                                        BOX11299
      NUPOWN= IUFON1
                                                                        30X10100
      XBRNOD=XBRVR1
                                                                        BOX10101
      RETURN
                                                                        BOX10132
 1010 FORMAT (11H *****BOX12)
                                                                        BOX10133
                                                                        BOX13104
      END
```

```
BOX10601
      SUBROUTINE BOX13 (INT, ICC, I EV, C2, SIGMAL, SIGMAU, XZ, S0, S1, SLOLD,
                          SUOLD, NE1, ND4, NE6, ND8)
                                                                                 BOX10LJ2
C TIGHTEN THE LIMITS ON THE MONOTONE VARIABLES (PHASE 1) OR TIGHTEN
                                                                                 BOX 10003
C THE LIMITS ON ALL VARIABLES USING THE BEST UPPER BOUNC (PHASE 2).
                                                                                 BOX 10604
      COMMON/P1/N, M, I TYPE, NST RAT, NODRL1, NBVRL1, NT ITE1, NODRL2, NB VRL2, NT ITE2, MXLIST, LISTOP, ITAPE, IFB, MXITER, MBINV, IQU TPT,
                                                                                 BOX10035
                                                                                 BOX10006
                 ITRACE, MSTART, TIME1, TOL1, TOL2, PCBL8, ALPHA (10)
                                                                                 BOX10007
     2
      COMMON/P2/EPSI, EPSIM, BIGN, BEGTM, M:, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2, BOX10008
                 NM1M3, N1P2, NP1, NSUM, NTC, M10
                                                                                 BOX10039
      COMMON/P3/NODNOT, UNOT, IBUBOP, LPHASE, NODRUL, NBVRUL, NTIGHT, NLIST,
                                                                                 BOX10010
                 NLISTS, NFEAS, LSTMX, ITRT CT, ITRMAX, BL E, NBRNOD, P BRNOD,
                                                                                 BOX10011
                 NBRVAR, NUPDHN, XERNOC, TBRNOD, NODE, LNODE, Z, BOUNDL, BCUNDU, BOX 10612
     3
                 TSIG, IFEAS, IBRVR1, IUPDN1, XBRVR1, IBRVR2, IUPDN2, XBRVR2,
                                                                                BOX10[13
                 LIC, NITER, NBINV, M7, I PHASE, NPHASE, NM3:17, IALGO, IEOJ
                                                                                 BOX10014
      DIMENSION INT (NC1), ICC (ND1) , I3V (NC4)
                                                                                 BOX 10015
      DIMENSION C2 (NO1), SIGMAL (NO6), SIGMAU(NO6), XZ(ND6), SO(ND8), S1(ND8), 30X13616
                 SLOLD (ND6), SUOL C(ND6)
                                                                                BOX10617
      IF (ITRACE.GE.1) HRITE(6, 1005)
                                                                                 BOX1JC18
      IF (NTIGHT.EQ.1) RETURN
                                                                                 BUX10019
      NCOUNT=0
                                                                                BOX 10020
      IF (UNOT.EQ. BIGNIGOTO310
                                                                                 90 X 10 C 21
      IF (IBUBOP.EQ.1) GO TO 310
                                                                                 B0X11922
                                                                              **30X10023
C TIGHTEN THE LIMITS ON THE BASIC VARIABLES.
                                                                                BOX 10 C 2 4
DO 30 0 I = 1, M7
                                                                                 30X10C26
      IF (I.EQ.MP1) GOTO 366
                                                                                 BOX10627
                                                                                 BOX10028
      J= IdV(I)
      IF (ABS(SIGHAU(J)-SIGMAL(J)).LE.TOL2)GOTO300
                                                                                 BOX13[29
      XZJJJ=XZ(J)
                                                                                 BOX10030
      IF (XZJJJ.GT.SIGMAL(J)+TOL2) GOTO100
                                                                                 BOX10[31
      SC(I)=-BIGN
                                                                                 BOX10032
      XZJJJ=SIGMAL(J)
                                                                                 BOX10033
      GOTU110
                                                                                 BOX10634
  100 IF (XZJJJ.LT.SIGMAU(J)-TOL2) GOTO110
                                                                                 BOX10635
      S1(I)=BIGA
                                                                                BOX13636
                                                                                 BOX 135 37
      XZJJJ=SIGMAU(J)
  110 CONTINUE
                                                                                BOX13638
C ALL VARIABLE TYPES.
                                                                                 BOX10039
      V1=SIGMAL(J)
                                                                                BOX13640
      IF (SO(I).EQ.-BIGN)GOTO120
T1=Z + SO(I)*(V1 - XZJJJ)
                                                                                 BOX10041
                                                                                 BOX10042
      GOT0130
                                                                                 BOX13643
  120 T1=BIGN
                                                                                 80X10C44
  136 IF (J.GT.N) GOT0230
                                                                                 BOX1 .. C.45
      IF (INT (J) . EQ . 0) GO TO 230
                                                                                BC . 10046
C INTEGER LINEAR OF INTEGER CONCAVE VARIABLE.
                                                                                 30X10C47
      K=XZJJJ
                                                                                 80X1JC48
      ¥2=K
                                                                                 BOX13549
      V3=K+1
                                                                                 BOX10050
      K=ICC(J)
                                                                                BOX13051
      IF (K.EQ.C) GOTO150
                                                                                BOX10052
      CALL GETOBJ (K, V1, F1)
                                                                                BOX10053
      CALL GETOBJ (K, V2,F2)
CALL GETOBJ (K, V3,F3)
                                                                                 BOX13654
                                                                                BOX10055
      IF (SO(I).EQ.-BIGN .AND. ABS(XZJJJ-V2).GT.TOL2)GOT0170
                                                                                 BOX10056
      IF (SO(I).EQ.-BIGN)GOTO140
                                                                                BOX10057
```

```
BOX10058
      T2=Z + SQ(I)*(V2 - XZJJJ) + F2 - (F1 + C2(J)*(V2-SIGMAL(J)))
 GOTO180
140 T2=Z + F2 - (F1 + C2(J)*(V2-SIGMAL(J)))
                                                                            BOX10059
                                                                            BOX13060
      GOT0180
                                                                            BOX10061
  150 1F(SO(I).EQ.-BIGN .AND. ABS(XZJJJ-V2).GT.TOL2)GOT0170
                                                                            BOX10062
      IF (SO(I).EQ.-BIGN)GOTO160
                                                                            BOX10063
      T2=Z + S0(I)*(V2 - XZJJJ)
                                                                            BOX10064
                                                                            BOX10165
      GOT0180
 160 T2=Z
                                                                            BOX10066
      GOTO180
                                                                            BOX10067
 170 T2=BIGN
                                                                            BOX13668
  180 IF (S1(I).EQ.BIGN .AND. ABS(V3-XZJJJ).GT.TOL2)GOTO220
                                                                            BOX10069
                                                                            BOX13070
      IF (K.EQ.0)G0T0200
      IF (S1(I).EQ. BIGN) GOTO190
                                                                            BOX10071
      T3=Z + S1(I)*(V3 - XZJJJ) + F3 - (F1 + C2(J)*(V3-SIGMAL(J)))
                                                                            BOX10172
                                                                            BOX13073
      GOT0260
  190 T3=2 + F3 - (F1 + C2(J)*(V3-SIGMAL(J)))
                                                                            BOX10574
                                                                            BOX10075
      GOT0260
                                                                            BOX13076
  200 IF ($1(I) . EQ . BIGN) GOTO 216
      T3=Z + S1(I)+(\3 - XZJJJ)
                                                                            BOX13077
                                                                            BOX19678
      GOT0260
                                                                            BOX10679
 210 T3=2
      GOT0260
                                                                            BOX10083
  226 T3=BIGN
                                                                            BOX10081
                                                                            BOX10082
      GOT0260
C LINEAR OR CONCAVE VARIABLE.
                                                                            80X10683
  236 V2=XZJJJ
                                                                            BOX10984
                                                                            BOX10085
      V3=V2
      IF (J.GT.N)GOTU240
                                                                             BOX10086
                                                                            BOX10087
      K=ICC(J)
      IF (K.EQ.C)GOTO240
                                                                            BOX10088
      CALL GETOBJ (K, V1,F1)
CALL GETOBJ (K, V2,F2)
                                                                            BOX10089
                                                                            BOX 10090
      T2=2 + F2 - (F1 + C2(J)*(V2-SIGMAL(J)))
                                                                            BOX13091
                                                                            BOX10092
      GOTO250
 240 T2=Z
                                                                            BOX10093
  250 13=12
                                                                            BOX13194
C ALL VARIABLE TYPES.
                                                                            80X10095
  260 V4=SIGMAU(J)
                                                                            BOX10096
                                                                            BOX10697
      IF (S1(I).EQ.BIGN) GOTO270
      T4=2 + S1(I)*(V4 - XZJJJ)
                                                                            BOX10098
                                                                            BOX10099
      GOTO280
  270 T4=31GN
                                                                            BOX10100
 280 CALL ADJUST (V1, V2, V3, V4, T1, T2, T3, T4, SL, SU)
                                                                            30×10101
      SIGHAL (J)=SL
                                                                            BOX10102
      SIGMAU(J)=SU
                                                                            BOX10163
                                                                            BOX10104
      IF (J.GT.N)GOT0290
      IF (INT(J) .EQ. 0) GO 10290
                                                                            BOX10105
C FOR INTEGER VARIABLES, CHECK THAT THE LONER AND UPPER LIMITS ARE
                                                                            80X1313€
C INTEGERS.
                                                                            BOX10107
      K= SL
                                                                            80X10108
      SIGHAL (J)=K
                                                                            BOX13139
      IF (ABS(SL - SIGMAL(J)).GT.TOL2) SI EMAL(J)=K+1
                                                                            BOX10110
                                                                            BOX10111
      K=SU
                                                                            BOX10112
      SIGMAU(J)=K+1
      IF (ABS(SU - SIGHAU(J)).GT.TOL2)SI (MAU(J)=K
                                                                            BOX10113
C INCREMENT THE COUNTER IF THE LIMITS HAVE CHANGED.
                                                                            BOX10114
```

```
290 IF (ABS(SIGNAL(J)-SLOLD(J)). GT.TOL 2) NCOUNT=NCOUNT+1
                                                                  BOX10115
     IF (ABS(SIGH AU(J)-SUOLO(J)).GT.TCL 2) NCOUNT=NCOUNT+1
                                                                  BOX10116
 300 CONTINUE
                                                                  BOX10117
     GOT0370
                                                                  BOX10118
C ADJUST THE LIMITS ON THE MONOTONE VARIABLES.
                                                                  BOX10120
C......
                                                                 **80X10121
 316 D0360I=1, M7
                                                                 BOX10122
     IF (I.EQ.MP1) GOT 0360
                                                                  BOX10123
                                                                BOX10124
     J=IAVII)
                                                           B0X10125
B0X10126
     IF (ABS(SIGHAU(J)-SIGHAL(J)).LE.TOL2)GOT0360
     (L) SX=LLLSX
     IF (XZJJJ.LE.SIGHAL(J)+TOL2) GOTO 330
                                                                 BOX10127
     IF (SO (I) . NE . - BIGN ) GOTO 330
                                                                  B0X10128
C ADJUST THE LOWER LIFIT.
                                                                  BOX15129
                                                                  BOX10131
     IF (J.GT.N)G010320
     IF (INT (J) . EQ. 6) GO TO 320
                                                                  BOX13131
                                                                  BOX10132
     K=XZJJJ
     SIGNAL (J) =K
                                                                  BOX10133
     IF (ABS(XZJJJ-SIGMAL'(J)).GT.TOL2)SIGMAL(J)=K+1
                                                                  BOX10134
                                                                  BOX13135
     GOTO 330
 320 SIGMAL(J)=XZJJJ
                                                                  BOX10136
 336 IF (XZJJJ.GE.SIGHAU(J) -TOL 2) GOTO 350
                                                                  BOX10137
     IF (S1(I).NE. BIGN) GOT 0350
                                                                  B0X10138
C ADJUST THE UPPER LIMIT.
                                                                  BOX10139
     IF (J. GT. N)GOTO340
                                                                  BOX 10 140
     IF (INT (J) .EQ. 3) GOTO 340
                                                                  BOX10141
                                                                  BOX12142
     K=XZJJJ
     SIGMAU(J)=K+1
                                                                  BOX10143
     IF (ABS(XZ.JJ-SIGHAU(J)) .GT.TOL2) SIGMAU(J)=K
                                                                  BOX10144
     GOTO350
                                                                  BOX10145
                                                                  BOX10146
 346 SIGMAU(J)=XZJJJ
C INCREMENT THE COUNTER IF THE LIMITS HAVE CHANGED.
                                                                 BOX10147
 350 IF (ABS(SIGMAL(J)-SLOLO(J)).GT.TOL 2) NCOUNT = NCOUNT+1
                                                                BOX10148
                                                                 BOX10149
     IF (A3S(SIGMAU(J)-SUOLD(J)).GT.TCL2) NCOUNT=NCOUNT+1
 360 CONTINUE
                                                                  BOX 10 150
C PRINT THE OLD AND NEW LIMITS. BOX10152
 376 IF (IOUTPT .LE . 2) RETURN
                                                                  BOX10154
     IF (UNOT.EG.BIGN)G (T0380
IF (I8UBOP.EQ.1) GO T0380
                                                                  BOX10155
                                                                  B0X10156
     WRITE(6,1000)NBRNUD
                                                                  BOX10157
     GOT 0390
 38C WRITE(6,1601)NORNCD
                                                                  BOX10159
 396 IF (NCOUNT.EQ.C) 60 10410
                                                                  BOX10166
     WRITE(6,1002)NCOU T
                                                                  BOX10161
     D0400I=1, H7
                                                                  BOX10162
     IF (I.EQ.MP1) GOT 0406
                                                                  BOX10163
                                                                  80×10164
     J= IBV(I)
     IF (ABS(SIGMAL(J)-SLOLD(J)).LE.TOL 2 .AND.
       ABS(SIGMAU(J)-SUOLD(J)). LE. TOL2)GOTO400
                                                                  BOX13165
                                                                 BOX10166
     WRITE(6,1003)J,SLCLG(J),SIGHAL(J),XZ(J),SIGHAU(J),SUOLD(J)
                                                                  BOX10167
 400 CONTINUE
                                                                  BOX10168
     GO TO 420
                                                                 BOX10169
 410 WRITE(6,1004)
                                                                  BOX10170
 420 CALL TIMEC
                                                                  BOX10171
```

RETURN	B0X10172
1000 FORMAT (1H0,50 (1H+)/52HOTIGHTEN THE LIMITS ON THE BASIC VARIABLES	FB0X10173
10R NODE ,15)	B0X10174
1001 FORMAT (1H0, 50 (1H+)/54H0 ADJUST THE LIMITS ON THE MONOTONE VARIABLE	SB0X14175
1 FOR NODE , 15)	B0X10176
1002 FORMAT (12HOTHERE HERE , 15,23H CHANGES TO THE LIMITS./	B0X10177
1 1HJ, 2X, 5HBASIC, 11X, 3HOLD, 14X, 3HNEW, 11X, 8HVARIABLE, 12X,	B0X10178
2 3HNEH, 14X, 3HOLD/1X, 8HVARIABLE, 2 (9X, 5HLOWER, 3X), 9X,	BOX11179
3 5HVALUE, 2(12X, 5HUPPER) /6X, 2(12X, 5HL IMIT), 17X,	BOX10180
4 2(12X,5HLIMIT)//)	BOX10181
10G3 FORMAT(3x,15,1x,5(2x,E15.6))	B0X10182
1004 FORMAT (37HGTHERE WERE NO CHANGES TO THE LIMITS.)	BOX1-183
1005 FORMAT(11H *****BOX13)	BOX10184
END	BOX10185

```
SUBROUTINE BOX15 (NZ, NP, IR, IA, INT, ICC, IS, AV, IBV, NBV, IUPPER, TC,
                                                                                 BOX10001
                           BORIG, RHS, C2, C1, BI, BN, U, PJ, BINV, XJ, SIGNAL,
                                                                                 BOX10002
                           SIGHAU, V, XZ, SO, S1, SLOLD, C20LD, B, ND1, ND2, ND3,
                                                                                 BOX10003
                                                                                 BOX10GG4
                           ND4, ND5, ND6, ND7, ND8, ND9)
C.SOLVE SUBPROGRAM LNODE.
                                                                                 BOX10005
      COMMON/P1/N, M, ITYFE, NSTRAT, NO CRL1, NOVRL1, NTITE1, NCDRL2, NAVRL2,
                                                                                 BOX10006
                  NTITE2, MXLIST, LISTOP, ITAPE, IFB, MXITER, MBINV, ICUTPT,
                                                                                 BOX10007
      ITRACE, MSTART, TIME1, TOL 1, TOL 2, PCBUB, ALPHA (10)
COMMON/PZ/EPSI, EPSIM, BIGN, BEGTM, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2,
                                                                                 80X10008
                                                                                 BOX10009
                  NH1H3, N1P2, NP1, NSUM, NTC, H10
                                                                                 30X10010
       COMMON/P3/NODNOT, UNOT, IBUBOF, LPHASE, NODRUL, NBVRUL, NTIGHT, NLIST,
                                                                                 BOX10611
                  NLISTS, NFEAS, LSTMX, ITRTCT, ITRMAX, BLB, NBRNOD, PBRNOD,
                                                                                 BOX10012
                  NBRVAR, NUPD HN, XBR NOD, TBRNOD, NODE, LNODE, Z, BOUNDL, BCUNDU,
                                                                                 B0X10613
                  TSIG, IF EAS, IORVR1, IUPDN1, XBRVR1, IBRVR2, IUFDN2, XBRVR2,
                                                                                 SOX 10014
                  L10, NITER, NBINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IEOJ
                                                                                 30X10015
       COMMON/P4/SAVE, KURAN, X1
                                                                                 BOX10016
       DIMENSION INT(ND1), ICC(ND1), IS(ND4), IBV(ND4), NBV(ND5), IUPPER(ND5) BOX10017
       DIMENSION BCRIG (NC4), RHS (NO4), C2 (ND1), BI (ND4), BN (ND5), U(ND6),
                                                                                 BOX10618
                  PJ(NO4),SIGHAL(NO6),SIGHAU(NO6),XZ(NO6),SLOLD(NO6),
                                                                                 BOX10019
                  C20LD (ND9) , 8 (ND4, ND4)
                                                                                 BOX10020
       IF (ITRACE.GE.1) WRITE(6,1015)
                                                                                 BOX10021
                                                                                 BOX10022
      NODE=NODE + 1
       IF (I CUTPT .NE . C) WRITE (6, 1000) NODE, NBRNOD
                                                                                 BOX10023
       IF (LNODE.EQ. 2) GCT 0290
                                                                                 B0X10024
                                                                     *************80X10025
C INITIALIZE THE DATA REQUIRED FOR SUBPROGRAM 1.
                                                                                 BOX10026
               IF (XBRNOD.LT.SIGMAL (NORVAR)) XORNO C=SIGMAL (NORVAR)
                                                                                 80X10C28
      IF (X BRNOD. GI.SIGMAU (NBRVAR) ) X BRNOC=SIGMAU (NBRVAR)
                                                                                 BOX10029
C MODIFY THE UPPER LIMIT FOR THE BRANCHING VARIABLE.
                                                                                 BOX10030
       SAVE = SIGH (U (NERVAR)
                                                                                 BOX10031
       IF (INT (NBRVAR) . NE . C )GOTO110
                                                                                 BOX10032
C BRANCHING ON A CONCAVE VARIABLE.
                                                                                 BOX10033
  100 IF (LOUTPT.NE. C) HRITE (6, 1001) NORVAF, ICC (NORVAR)
                                                                                 BOX10034
      SIGMAU(NBRVAR) = XBRNOD
                                                                                 BOX10035
       KBRAN=0
                                                                                 BOX10036
       GOTO120
                                                                                 BOX10037
C BRANCHING ON AN INTEGER VARIABLE.
                                                                                 BOX10038
  110 K=XBRNOD
                                                                                 BOX10039
      XC=K
                                                                                 BOX10C40
       X1=K+1
                                                                                 BOX10041
      IF (ABS(X0-XBRNOD).LE.TOLZ .AND. ICC(NBRVAR).NE.G)GOTO100
IF (ABS(X1-XBRNOG).LE.TOLZ .AND. ICC(NBRVAR).NE.G)GOTO100
                                                                                 BOX10042
                                                                                 BOX10043
      IF (IOUTPT.NE. G) WRITE (6,1002) NORVA F, INT (NERVAR)
                                                                                 BOX10044
       SIGHAU(NBRVAR) = XG
                                                                                 BOX10045
       KBRAN=1
                                                                                 BOX10046
C ESTABLISH THE UPPER LIMITS FOR SUBPROGRAM 1.
                                                                                 BOX10047
  126 D0130J=1, N1P2
                                                                                 BOX10048
  130 U(J)=SIGMAU(J) - SIGMAL(J)
                                                                                 BOX 10649
C ESTABLISH THE COST DATA FOR SUBPREGRAP 1.
                                                                                 BOX10650
                                                                                 BOX10051
      D0140J=1, N
  140 TBRNOD=TBRNOD + C2(J)+(SIGHAL(J) - SLOLD(J))
                                                                                 BOX10052
       TSIG=TBRNCO
                                                                                 BOX10053
C ESTABLISH THE RIGHT-HAND-SIDE FOR SUSFROGRAM 1.
                                                                                 BOX 10054
       00150I=1, M7
                                                                                 BOX10055
  150 RHS(I)=80FIG(I)
                                                                                 BOX10056
      D0180J=1,N1P2
                                                                                 BOX10057
```

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BOX18858
      IF (ABS(SIGHAL(J)).LE.EPSI)GOTO180
      00160I=1,H7
                                                                               BOX10659
  160 PJ(1)=0.0
                                                                               BOX 10060
      CALL GETCOL (NZ,NP,IR,IA,IS,TC,RHS,C2,C1,PJ,NC1,NE2,ND3,ND4,ND5,
                                                                               BOX10061
                                                                               BOX10662
                    J, NZERCS)
      0017011=1.NZEROS
                                                                               B0X10063
                                                                               BOX10064
      I=IS(I1)
  170 RHS(I)=RHS(I) - PJ(I) *SIGMAL(J)
                                                                               BOX10065
      IF (IPHASE.E4.2) RHS (MP2) = RHS (MP2) - PJ(MP2) +SIGNAL (J)
                                                                               BOX10066
  180 CONTINUE
                                                                               BOX10067
C ESTABLISH THE BASIS INVERSE, THE VALUES OF THE BASIC VARIABLES, AND C THE VALUES OF THE NONEASIC VAFIABLES FOR SUBPROGRAM 1.
                                                                               BOX10668
                                                                               80X10069
                                                                               BOX10070
      00190K=1.L10
      IF (IUPPER (K) .EQ. 0) GOT 0190
                                                                               BOX10071
      J=NBV(K)
                                                                               BOX10072
      BN(K)=U(J)
                                                                               BOX10073
  196 CONTINUE
                                                                               BOX10074
      IF (LISTOP.EQ.1) 60 10270
                                                                               BOX10075
      DO 2001=1, M7
                                                                               BOX10076
  200 BI(I)=RHS(I)
                                                                               BOX10077
      00230K=1,L10
                                                                               BOX10078
      IF (IUPPER (K) .EQ. 0) GOT 0230
                                                                               BOX10079
                                                                               BOX10080
      J=NBV(K)
                                                                               BOX10081
      IF (ABS(U(J)) .LE.EPSI) GOTO230
      D0210I=1, H7
                                                                               BOX10082
                                                                               BOX10083
  210 PJ(I)=0.0
      CALL GETCOL (NZ,NP,IR,IA,IS,TC,RHS,C2,C1,PJ,ND1,ND2,ND3,ND4,ND5,
                                                                               BOX 13084
                    J.NZEROS)
                                                                               BOX10085
      DO220I1=1,NZEROS
                                                                               BOX10086
                                                                               BOX10087
      I=IS(I1)
  220 BI(I)=BI(I) - PJ(I)*U(J)
                                                                               BOX10088
      BI (MP1)=BI(MP1) - PJ(MP1)*U(J)
                                                                               BOX10089
      IF (IPHASE.EQ.2) 81 (MP2)=81 (MP2) - PJ (MP2)*U(J)
                                                                               BOX13096
                                                                               BOX10091
  230 CONTINUE
      D0250I=1, M7
                                                                               BOX10092
      Q1=0.0
                                                                               BOX10093
      D0240J=1, M7
                                                                               BOX10094
  240 Q1=Q1 + B(I,J)*BI(J)
                                                                               BOX10095
  250 PJ(I)=Q1
                                                                               BOX10096
                                                                               BOX10097
      D0260I=1, M7
  260 BI(I)=PJ(I)
                                                                               BOX10098
      GOTO280
                                                                              BOX10099
  270 CALL BINVRT (NZ,NF,IR,IA,IS,IBV,NBV,IUPPER,TC,RHS,C2,C1,BI,U,PJ,
                                                                              BOX10100
                   BINV, B, NO1, NO2, NO3, N (4, NO5, NO6, NO7)
                                                                               BOX10101
  280 REWIND 4
                                                                               BOX10102
      WRITE(4)(IBV(I), I=1, ND4), (NBV(I), I=1, ND5), (IUPPER(I), I=1, ND5),
                                                                              BOX10103
               (BI(I), I=1, ND4), (BN(I), I=1, ND5), L1C, NITER, NBINV,
                                                                               BOX10104
               ((B(I,J),I=1,ND4),J=1,ND4)
                                                                               BOX10105
C CHECK IF THE SUBPROGRAM IS INCLUDED IN THE NEXT SUBPROGRAM.
                                                                              BOX10106
      IF (INT (NBRVAR) . NE. C)GOTO370
                                                                              BOX10107
      IF (ABS(U(NBRVAR)) .GT.TOL2)GOT0370
                                                                              BOX10108
      IF (ABS(SAVE - SIGNAL(NBRVAR)).LE.TOL2)GOT0370
                                                                              BOX10109
                                                                              BOX10110
      IEOJ=1
      IF (IOUTPT.NE.C) WKITE(6, 1604)
                                                                              BOX10111
      RETURN
                                                                              BOX10112
                                                                 **************BOX10113
C INITIALIZE THE DATA REQUIRED FOR SUBPROGRAM 2.
                                                                              BOX10114
```

```
290 SIGNAUINBRVAR) = SAVE
                                                                          BOX10116
      SAVE = SIGHAL (NBRVAR)
                                                                          BOX10117
      IF (KBRAN.EQ .1)GOTO300
                                                                          BOX10118
      IF (IOUTPT.NE.D) WRITE (6, 1001) NBRVAF, ICC (NBRVAR)
                                                                          BOX10119
                                                                          BOX10 120
      SIGNAL (NBRVAR) = XBRNOD
      GOTO 310
                                                                          ROX10121
  300 IF (IOUTPT.NE. 0) WRITE(6, 1002) NBRVAR, INT (NBRVAR)
                                                                          BOX10122
      SIGNAL (NBRVAR) = X1
                                                                          BOX10123
  310 DELTA=SIGMAL (NBRVAR) - SAVE
                                                                          BOX10124
C ADJUST THE UPPER LIMITS.
                                                                          BOX10125
      U(NdRVAR)=SIGMAU(NBRVAR) - SIGMAL (NBRVAR)
                                                                          BOX10126
C AUJUST THE COST DATA.
                                                                          BOX10127
      IF (ITYPE.EQ.1)GOTO330
                                                                          BOX10128
      D0320J=1,N
                                                                          BOX10129
                                                                          BOX 10 130
  320 C2(J)=C20LD(J)
  330 TSIG=TBRNCD + C2(NBRVAR) +DELTA
                                                                          BOX10131
                                                                          BOX10132
C ADJUST THE RIGHT-HAND-SIDE.
      00340I=1,K7
                                                                          BOX10133
                                                                          BOX10134
  340 PJ(I)=0.0
      CALL GETCOL (NZ,NP,IR,IA, IS,TC,RHS,C2,C1,PJ,ND1,NC2,ND3,ND4,ND5,
                                                                          BOX10135
                   NBRVAR, NZEROSI
                                                                          BOX10136
      0035011=1 .NZEROS
                                                                          BOX10137
                                                                          BOX10138
      I=IS(I1)
  350 RHS(I)=RHS(I) - PJ(I)+DELTA
                                                                          BOX10139
      IF (IPHASE.EQ. 2) RHS (MP2) = RHS (MP2) - PJ (MP2) DELTA
                                                                          80X10140
C ADJUST THE VALUES OF THE BASIC VARIABLES.
                                                                          BOX10141
                                                                          BOX10142
      RENIND 4
      READ (4)(IBV(I), I=1, ND4), (NBV(I), 1=1, ND5), (IUFPER(I), I=1, ND5),
                                                                          BOX16143
              (BI(I), I= 1, ND4), (BN(I), I=1, ND5), L10, NITER, NJINV,
                                                                          BOX10144
              ((B(I,J), I=1,NO4),J=1,NO4)
                                                                          BOX10145
     2
      DO360I=1, M7
                                                                          B0X10146
      BI(I)=BI(I) + B(I, MP1)*PJ(MP1)*DELTA
                                                                          BOX10147
      IF (NBRYAR.NE. IBV(I))GOTO360
                                                                          BOX16148
      81 (1) =81 (1) - DEL TA
                                                                          BOX10149
360 CONTINUE C CHECK IF THE SUBPROGRAM IS INCLUDED IN THE LAST SUBPRIGRAM.
                                                                          80 X 10 15 U
                                                                          BOX10151
      IF (INT (NORVAR) . NE. 0 1GOT 03 70
                                                                          BOX10152
      IF (ABS (U(NBRVAR)) . GT. TOL2)GOT0370
                                                                          BOX10153
      IEOJ=1
                                                                          80X10154
      IF (IOUTPT.NE.6) PRITE(6, 1005)
                                                                          BOX10155
      RETURN
                                                                          BOX10156
C SOLVE SUBPROGRAM LNCOE.
                                                                          BOX10158
                                                                         *B0X10159
 37.0 IEOJ=0
                                                                          BOX10 160
      D0390J=1,N1P2
                                                                          BOX10161
      IF (U(J) .LT.-TOL2) 60T0380
IF (U(J) .GE.TOL2*0.1)60T0390
                                                                          BOX10162
                                                                          BOX10163
      U(J)=TOL2*8.1
                                                                          BOX10164
      GOTO 390
                                                                          BOX10165
 380 IEOJ=1
                                                                          BOX10166
 390 CONTINUE
                                                                          BOX10167
      IF (IEOJ.EQ. 0) GOTO 410
                                                                          BOX10168
C THE LOWER AND UPPER LIMITS ARE INCOMPATIBLE.
                                                                          BOX10169
      IF (IOUTPT.NE.G) MRITE(6,1006)
                                                                          BOX10170
      IF (IOUTPT .LE . 1) RETURN
                                                                          BOX10171
```

```
WRITE(6,1007)
                                                                              BOX10172
                                                                              BOX10173
      D0450J=1:N1P2
      1F (U(J) .GE. -TOL2)GOT0400
                                                                               BOX10174
      WRITE(6,1008)J, SIGMAL(J), SIGMAU(J)
                                                                               BOX10175
                                                                              BOX10176
  460 CONTINUE
      RETURN
                                                                              BOX10177
C THE LOWER AND UPPER LIMITS ARE COMPATIBLE.
                                                                              BOX10178
  416 IF (ITYPE.EQ. 2)6010460
                                                                               BOX10179
                                                                              BOX10 180
C APPLY THE DUAL SIMPLEX ALGORITHM FIRST.
      IF (IOUTPT . LE . 1) GO TO 450
                                                                              BOX10181
      WRITE(6,1003)TSIG
                                                                              B0X10182
                                                                              BOX10183
      WRITE (6,1009)
                                                                              BOX10184
      00430J=1,N
      K=INT(J)
                                                                              BOX13185
                                                                              BOX10186
      L=ICC(J)
      IF (10UTPT .GE. 3) GO 10420
                                                                               80X10187
      IF (K. EQ. C . ANU. L. EQ. 0) GOTO 430
                                                                              B0X13188
  420 HRITE(6,1010)J,K,L,SIGMAL(J),SIGMAU(J),C2(J)
                                                                              BOX10189
  430 CONTINUE
                                                                              BOX10190
      IF (IOUTPT.LE.2) GO 10450
                                                                               BOX13191
                                                                              BOX10192
      IF (NM1M3.EQ. A) GOT C450
      D0440J=NP1,NM1M3
                                                                              30X10193
  440 WRITE(6,1011) J. SIGMAL (J) , SIGMAU(J)
                                                                              BOX15194
  456 TALGO=2
                                                                              BOX13195
      CALL SIMPLE "IZ,NP, IR, IA, IS, NV, IBV, NBV, IUFPER, TC, FHS, C2, C1, BI, BN, BOX10196
                   U,PJ,BINV,XJ,V,XZ,B,ND1,ND2,ND3,ND4,ND5,ND6,ND7)
                                                                              BOX13197
      IF (IEOJ.NE. 0) RETURN
                                                                               30X10198
  460 IF (ITYPE.EQ. 1) GOTO580
                                                                               BOX13199
C APPLY THE PRIVAL ALGORITHM SECOND.
                                                                              BOX10 200
                                                                              BOX13231
C ESTABLISH NEW COST DATA.
      TS1G=0.0
                                                                              BOX10202
      D0490J=1,N
                                                                               BOX10293
      K=ICC(J)
                                                                              BOX10234
      IF (K.EQ.C)GOTO480
                                                                               BOX132.5
      CALL GETOBJ (K, SIGMAL (J), FO)
                                                                              BOX10216
      TSIG=TSIG + FC
                                                                              BOX10207
      IF (ABS (U(J)) . LE.TOL 2) GOT 0479
                                                                              BOX10268
                                                                              BOX10209
      CALL GETOBJ (K, SIGMAU(J), F1)
      C2(J)=(F1 - F6)/U(J)
                                                                              BOX13213
      6010490
                                                                              BOX10211
  470 C2(J)=0.0
                                                                              BOX10212
                                                                              BOX10213
      GOT0490
  480 TSIG=TSIG + C2(J) *SIGMAL(J)
                                                                              BOX13214
                                                                              BOX13215
  490 CONTINUE
                                                                              BOX10216
      IF (10UTPT.LE.1) GO TO 530
      WRITE (6,1003) TSIG
                                                                              BOX10217
                                                                              B0X10218
      WRITE(6,1009)
                                                                              BOX10219
      DO5 10 J= 1, N
      K=INT(J)
                                                                              BOX 10 220
                                                                              BOX13221
      L=TCC(J)
      IF (IOUTPT.GE.3) 60 TO 500
                                                                              BOX13222
      IF (K.EQ.0 .AND. L.EQ. 0) GOTO510
                                                                              BOX10223
  500 WRITE (6,1010) J, K, L, SIGNAL (J), SIGNAU (J), C2(J)
                                                                              B0X13224
  510 CONTINUE
                                                                              BOX10225
      IF (IOUTPT.LE.2) GO TO 530
                                                                              BOX10226
                                                                              B0X10227
      IF (NH1H3.EQ. N) GCT C530
      D0520J=NP1, NH1H3
                                                                              B0X10228
```

```
520 MRITE(6,1011)J,SIGMAL(J),SIGMAU(J)
530 INDEX=0
                                                                                      BOX18229
                                                                                      BOX10230
C BASIC VARIABLES.
                                                                                      BOX18231
       00550I=1, F7
                                                                                      BOX10232
       IF (I.EG.MP1) GOTOSSO
                                                                                      BOX10233
       (I)VEI=L
                                                                                      BOX10234
       IF (J.GT.N)GOTO550
                                                                                      BOX10235
       T=CZ(J) - CZOLD(J)
                                                                                      BOX10236
       IF (ABS(T) .LE.EPSI )GOTO550
                                                                                      BOX10237
       I NOF Y=1
                                                                                      ROY10238
       BI (MP1) = BI (MP1) - T*BI(I)
                                                                                      BOX10239
       D0540J=1,H7
                                                                                      BOX 10 240
  540 B(MP1,J)=B(MP1,J) - T*B(I,J)
                                                                                      BOX10241
  558 CONTINUE
                                                                                      80X10242
C NONBASIC VARIABLES.
                                                                                      BOX10243
       00560I=1,L10
                                                                                      BOX10244
       J=NAV(T)
                                                                                      BOX10245
                                                                                      B0X1024 E
       IF (J.GT.N)GCT0560
       T=C2(J) - C20LD(J)
                                                                                      BOX10247
       IF (ABS(T) .LE . EPSI)GOTO560
                                                                                      BOX10248
       INDEX=1
                                                                                      BOX10249
  560 CONTINUE
                                                                                      BOX10 250
       IF (INDEX.EQ. 0) GOTO570
                                                                                      BOX10251
       IALGO=1
                                                                                      BOX10252
       CALL SIMPLE (NZ,NP,IR,IA,IS,NV,IBV,NBV,IUPPER,TC,RMS,C2,C1,BI,BN, BOX10253 U,PJ,BINV,XJ,V,XZ,B,ND1,ND2,ND3,ND4,ND5,ND6,ND7) BOX10254
       IF (IEOJ.NE. 0) RETURN
                                                                                      BOX10255
       GOT0580
                                                                                      BOX10256
  570 IF (10UTPT.GE.2) WRITE (6,1012)
                                                                                      BOX10257
580 NFEAS=NFEAS + 1
C PRINT THE SOLUTION.
                                                                                      BOX10258
                                                                                      BOX10259
       Z=Z + TSIG
                                                                                      BOX 10 260
       D0590J=1,N1P2
                                                                                      BOX10 261
  590 XZ(J)=XZ(J) + SIGMAL(J)
                                                                                      BOX10262
       IF (IOUTPT.EQ.0) 60 TO 600
                                                                                      BOX10263
                                                                                      B0X10264
       NUP=N
       IF (IOUTPT .GE . 3) NUP=NM1M3
                                                                                      BOX10265
                                                                                      BOX10266
       WRITE(6,1013) Z
       WRITE(6,1014)(XZ(J),J=1,NUP)
                                                                                      BOX10267
  600 IF (NOVRUL.GE.3 .AND. NTIGHT.EQ.1) RETURN
                                                                                      B0X10268
C DETERMINE THE SLOPES ASSOCIATED WITH THE OPTIMAL OBJECTIVE VALUE.
                                                                                      BOX10269
      CALL SLOPES (NZ,NF,IR,IA,IS,IBV,NBV,IUPPER,TC,RHS,C2,C1,PJ,XJ,S0, BOX10270
S1,B,ND1,ND2,ND3,ND4,ND5,NCB) BOX10271
                                                                                      BOX10272
 1000 FORMAT(1H0,50(1H0)/EHONODE ,15/20HOBRANCHED FROM NODE ,15) BOX10273
1001 FORMAT(23HOBRANCHING ON VARIABLE ,15,27H WHICH IS CONCAVE VARIABLEBOX10274
                                                                                      BOX10275
     1 ,15)
 1002 FORMAT(23H0 BRANCHING ON VARIABLE ,15,27H WHICH IS INTEGER VARIABLEBOX10276
     1 ,15)
                                                                                      BOX10277
 1003 FORMAT (7HOTSIG =. E15.6)
                                                                                      BOX10278
 1004 FORMAT (76HOTHE SUBPROGRAM NEED NOT BE SOLVED AS IT IS INCLUDED IN BOX10279
     1THE NEXT SUEPROGRAM.)
                                                                                      BOX10280
 1005 FORMAT(76HOTHE SUBPROGRAM NEED NOT BE SOLVED AS IT IS INCLUDED IN BOX10281
     1THE LAST SUBPROGRAM.)
                                                                                      BOX10282
 1006 FORMAT (27HOTHE PROGRAM IS INFEASIBLE.)
                                                                                      BOX1028J
 1007 FORMAT(38H5THE FOLLCWING LIMITS ARE INCOMPATIBLE/
1 9HOVARIABLE, 9X, 5HLCMER, 12X, 5HUPPER/
                                                                                      BOX10264
                                                                                      BOX10285
```

24.6HNUMBER.1G4.5HLTMTT.124.5HLTMTT//)	B0X10286
	BOX10287
	B0X10288
4HCO ST/2X, EHNUHJER, 3X, 8HVA FIABLE, 2X, 8HVARIABLE, 9X, 5HLIMIT,	BOX10289
12X, 5HLIKIT, 9X, 11HCOEFFICIENT/12X, 6HNUMBER, 4X, 6HNUMBER//)	BOX10 290
MAT(3X,15,2(5X,15),3X,3(£15.6,2X))	BOX10 291
MAT(3X,15,23X,E15.6,2X,E15.6)	BOX10292
MAT(29HOTHE LAST TABLEAU IS OPIIMAL.)	80X10293
MAT(17HGSOLUTION VALUE =, £15.6)	BOX10294
MAT(17H0VARIABLES =,6E15.6/(17X,6E15.6))	80X10295
	BOX10296 BOX10297
֡	MAT(3X,15,2(5X,15),3X,3(£15.6,2X)) MAT(3X,15,23X,£15.6,2X,£15.6) MAT(29HOTHE LAST TABLEAU IS OPTIMAL.) MAT(17HÚSOLUTICN VALUE =,£15.6)

```
SUBROUTINE BOX17 (INT, ICC, IBV, C2, SIGMAL, SIGMAU, XZ, S0, S1, ND1, ND4,
                                                                                  BOX 10001
                           ND6, ND8)
                                                                                  BOX10002
C DETERMINE LOWER BOUND. SELECT THE BRANCHING VARIABLE.
COMMON/P1/N, H, ITYPE, NSTRAT, NODRL1, NBVRL1, NTITF1, NODRL2, NBVRL2,
                                                                                  BOX10003
                                                                                  80X10004
                  NTITE2, MXLIST, LISTOP, ITAPE, IFE, MXITER, MBINV, IOUTPT,
                                                                                  BOX10005
                  ITRACE . MSTART , TIME1 , TOL1 , TOL2 , PCBUB, ALPHA (10)
                                                                                  BOX10006
      COMMON/P2/EPSI, EPSIM, BIGN, BEGTM, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2, BOX10007
                  NM1H3. N1P2.NP1.NSUM.NTC, M10
                                                                                  BOX10008
     1
      COMMON/P3/NOCNOT, UNOT, IBUBOP, LPHASE, NOORUL, NBVRUL, NTIGHT, NLIST,
                                                                                  BOX10009
                  NLISTS, NFEAS, LSTMX, ITRTCT, ITRMAX, BLB, NBRNOD, PBRNOD.
                                                                                  BOX10010
     2
                  NBRVAR, NUPDWN, XBRNOD, TBRNOD, NODE, LNODE, Z, BOUNDL, BOUNDU, BOX10011
     3
                  TSIG, IFEAS, IBRVR1, IUPDN1, XBRVR1, IBRVR2, IUPDN2, XBRVR2,
                                                                                  80X10012
                  L10, NITER, NBINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IEOJ
                                                                                  BOX10013
      COMMON/P5/IRCUND
                                                                                  BOX10014.
      DIMENSION INT(NO1), ICC(NO1), IBV (NO4)
                                                                                  BOX10015
      DIMENSION C2 (ND1), SIGMAL (ND6), SIGMAU (ND6), XZ (ND6), SO (ND8), S1 (ND8) BOX10016
      IF(ITRACE.GE.1) HRITE(6,1009)
                                                                                  80X10017
       IF (N8VRUL.EQ.5) GO 10420
                                                                                  B0X10018
                                                                                  BOX10019
       IF (NBVRUL.GE.3) GOTO250
                                                                                  *B0X10020
C MAXMIN AND MAXMAX BRANCHING VARIABLE SELECTION RULES.
                                                                                  BOX 10021
                                                                                  BOX10022
      BOUNDU= Z
                                                                                  BOX10023
      BOUNDL=Z
                                                                                  BOX10024
      PENO=Z
                                                                                  BOX10025
                                                                                  BOX10026
      PEN 1=7
      PEN2=Z
                                                                                  BOX 10027
      IBRV=0
                                                                                  B0X10028
       JBRV=0
                                                                                  BOX10029
      KBRV=0
                                                                                  BOX10030
      IFEAS=1
                                                                                  BOX 10031
C BEGINNING OF LOOP.
                                                                                  BOX10032
      D02401=1.M7
                                                                                  BOX 10033
      IF(I.EQ. MP1) GOTO240
                                                                                  BOX10034
       J=IBV(I)
                                                                                  BOX 10035
                                                                                  BOX10036
       IF(J.GT.N)GOT0240
      IF(ICC(J).NE.0)GOTO120
                                                                                  BOX10037
      IF(INT(J).EQ.0) G010240
                                                                                  BOX10038
C INTEGER LINEAR VARIABLE.
                                                                                  BOX10039
      K=XZ(J)
                                                                                  BOX10040
      X0=K
                                                                                  BOX10041
      X1=K+1
                                                                                  BOX10042
      IF (ABS (XZ(J) -X0) .LE. TOL 2) GOTO 240
                                                                                  BOX10043
                                                                                  80X10044
      IF(ABS(X1-XZ(J)).LE.TOL2)GOT0240
      IFEAS=0
                                                                                  BOX10045
      PO=RIGN
                                                                                  BOX10046
      P1=PQ
                                                                                  BOX10047
      IF (SO(I) .EQ. -BIGN) GOTO100
                                                                                  BOX10048
      PO=Z + SO(I)*(X0 - XZ(J))
                                                                                  BOX10049
  100 IF(S1(I).EQ.BIGN)GOTO110
                                                                                  BOX10050
      P1=Z + S1(I)*(X1 - XZ(J))
                                                                                  BOX10051
  110 IF (184V.EQ. 0) IBRV=J
                                                                                  BOX10052
      IF (JBRV.NE. 0) GOT 0190
                                                                                  BOX 10053
      JBRV=J
                                                                                  BOX10054
       JUPON= 2
                                                                                  BOX 1 0055
      IF(P1.LE.P0)GOT0190
                                                                                  BOX10056
      JUPON=1
                                                                                  BOX 10057
```

```
GOTO190
                                                                               ROX10058
  120 IF (INT (J) .NE. 0) GO TO 160
                                                                               BOX10059
C CONCAVE VARIABLE.
                                                                               BOX10060
  130 1F (ABS(XZ(J)-SIGNAL(J)).LE.TOL21GCT024G
                                                                               BOX10061
      IF (ABS(SIGMAU(J)-XZ(J)).LE.TOL2 1GOT024C
                                                                               BOX10062
      K=ICC(J)
                                                                               BOX10063
      CALL GETOBJ (K,SI(MAL(J),FO)
CALL GETOBJ (K,XZ(J),F1)
                                                                               B0x10064
                                                                               BOX10665
      DELTA=F1 - (FS + C2(J)*(XZ(J)-SIGMAL(J)))
                                                                               BOX13066
      AT JELTA + UDMJOE =UDMUOB
                                                                               BOX10067
      PG=Z + DELTA
                                                                               BOX10068
      P1=P0
                                                                               BOX10069
      IF (SO(I).EQ.-BIEN) GOT 0140
                                                                               80X1007G
      TG=Z + SO(I)*(SIGMAL(J) - XZ(J))
                                                                               BOX13071
      IF (TO.LT.PO) PO=TO
                                                                               BOX10172
  140 1F (S1(I) . EQ . BIGN) GOTO 150
                                                                               BOX10073
      T1=Z + 51(I) + (SIGMAU(J) - XZ(J))
                                                                               80X13E74
      IF (T1.LT.P1)P1=T1
                                                                               BOX10075
  156 IF (OELTA.EQ. 0.0 )GOTO190
                                                                               BOX10076
      IF (IBRV.EQ. 3) IBRV=J
                                                                               BOX10677
      IF (JBRY .NE. 0) GOTO 190
                                                                               BOX13C78
      JBRV=J
                                                                               BOX13679
      JUPUN=2
                                                                               BOX 10 ( 8C
      IF (P1.LE.P0) GOTO1 90
                                                                               BOX10081
      JUPHN=1
                                                                               BOX10082
                                                                               BOX10683
      GOTU193
C INTEGER CONCAVE VARIABLE.
                                                                               30X10L84
  160 K=XZ(J)
                                                                               BOX10(85
      XU=K
                                                                               B0X10086
      X1=K+1
                                                                               BOX10687
      IF (ABS (XZ(J)-XC).LE.TOL2)GOTO130
                                                                               B0X10088
      IF (ABS(X1-XZ(J)).LE.TOL2)GOTO130
                                                                               BOX10C83
      IFE IS=0
                                                                               BOX10090
      K=ICC(J)
                                                                               BOX10091
      CALL GETOBJ (K, SICHAL(J), FO)
                                                                               BOX10092
      CALL GETOBJ (K, XC,F1)
CALL GETOBJ (K, X1,F2)
                                                                               BOX10093
                                                                               BOX 10094
      FU=3IGN
                                                                               BOX10095
      P1=P0
                                                                               BOX10096
      IF (SO(I).EQ.-BIGN)GOTO170
                                                                               BOX10097
      PG=Z + S0(1)+(X0-XZ(J)) + F1 - (FC + C2(J)+(X0-SIGHAL(J)))
                                                                               BOX10098
      IF (ABS(XO-SIGMAL(J)).LE.TOL2)GOT0170
                                                                               BOX10099
      TO=Z + SO([]*(SIGMAL(J)-XZ(J))
                                                                               BOX10100
      IF (TO .LT.PO) PC=TC
                                                                               BOX10161
  176 IF (S1(1) . EQ. 81GN) GOTO 186
                                                                               BOX10102
      P1=Z + S1(I)*(X1-XZ(J)) + F2 - (F1 + C2(J)*(X1-SIGMAL(J)))
                                                                               BOX 10103
      IF (ABS(SIGNAU(J)-X1).LE.TOL 2)GOTO180
                                                                               BOX10104
      T1=Z + S1(I)*(SIGMAU(J)-XZ(J))
                                                                               BOX10105
      IF (T1.LT.P1) P1=T1
                                                                               80X1010€
  180 IF (IBRV.EQ.O) IBRV=J
                                                                               80X10107
      IF (JBRV.NE. 0)GOTO190
                                                                               BOX10168
      JBRV=J
                                                                               BOX10109
      JUPDN=2
                                                                               BOX10110
      IF (P1.LE.P0)GOTO150
                                                                               BOX10111
      JUPDN=1
                                                                               BOX10112
C ALL VARIABLE TYPES.
                                                                               BOX10113
C DETERMINE THE LONER BCUND.
                                                                               BOX10114
```

190	PENA=P0	BOX10115
	IF (P1.LT.PENA)PENA=P1	BOX10116
	IF(PENA.LE.BOUNDL)GOTO200	BOX10117
	BOUNDL=PENA	BOX10118
200	IF ((SO(1).EQBIGN .OR. S1(1).EQ.BIGN) .AND. NTIGHT.EQ.C)GOTO240	80X10119
	ERNINE THE MAXMIN SELECTION.	BOX10120
	IF(PENA.LE.PENO)GCTO210	B0X10121
	PE NJ = PE NA	BOX10122
	18RV=J	BOX10123
C DETE	ERMINE THE MAXMAX SELECTION.	80X10124
210	PEN8=P3	BOX10125
	JUD= 2	B0X10126
	IF (P1.LE.PEN8) GOTO220	B0X10127
	PENB=P1	BOX10128
	JU0=1	B0X10129
220	IF (PENB.LE.PEN1)GOT0230	BOX10130
	PEN1=PENB	BOX10131
	JUPO N=JUO	BOX10132
	JBRV=J	BOX10133
	ERMINE THE MAXMAX SELECTION TAKEN OVER THOSE VARIABLES FOR WHICH	BOX10134
	MIN IS GREATER THAN Z.	B0X10135
23.0	IF (ABS(PENA - Z).LE.EPSI)GOTO240	BOX10136
	IF (PENB.LE.PEN2) GOTO240	BOX10137
	PEN2=PEN8	BOX10138
	KUPON=JUD	BOX10139
	KBRV=J	BOX10140
	CONTINUE	B0X13141
CEND	OF LOOP.	B0X10142
-	G0T0290	50X10143
100	ED INTEGER LINEAR FROGRAM WITH THE MOST NONINTEGER	BOX10145
	NEIGHTED NCHINTEGER ERANCHING VARIABLE SELECTION RULE.	80X10146

	BOUNOU= Z	B0X10148
	BOUNDL=Z	B0X10149
	PEN1=0.0	BOX10150
	PEN2=0.0	BOX10151
	JBRV=0	B0X10152
	KBRV=0	B0X10153
	IFE #S=1	BOX10154
C BEGI	INNING OF LOOP.	BOX10155
	D0280I=1, H7	B0X1015 €
	IF(I.EQ.MP1)GOTO286	BOX10157
	J=18V(1)	BOX10158
	IF (J.GT.N)GOTO280	BOX10159
	IF(INT(J).EQ.C)GOTO280	BOX10160
	K=XZ (J)	B0X10161
	X0=K	BOX10162
	P0=XZ(J) - X0	BOX10163
	P1=1.0 - P0	BOX10164
	IF (PO.LE. TOL2)GOTO280	90X10165
	IF (P1.LE. TOL2) GOTO 280	BOX10166
	IFEAS=0	B0X10167
COETE	EMINE THE MOST NONINTEGER SELECTION.	B0X10168
	PENB=P0	B0X10169
	JUD=1	80X10.70
	IF (P1.GE.PENB) G07 9260	B0X10171

```
PENE=P1
                                                                     BOX10172
                                                                     BOX10173
      JU0=2
 260 IF (PENB. LE. PEN1) GOTO270
                                                                     BOX10174
                                                                     BOX10175
     PEN1=PENB
                                                                     BOX10176
     JUP CN=JUD
                                                                     BOX10177
      JBRV=J
C DETERMINE THE WEIGHTED NONINTEGER SELECTION.
                                                                     BOX10178
  270 PENE=PENB+ABS(C2(J))
                                                                     BOX10179
                                                                     BOX10180
      IF(PENB.LE.PEN2)GOTO280
     PEN2=PENB
                                                                     BOX10181
     KUP DN= JUD
                                                                     BOX10182
                                                                     BOX10183
     KBRV=J
                                                                     BOX10184
  280 CONTINUE
                                                                     BOX10185
C END OF LOOP.
      C COMMON LOGIC FOR MAXMIN, MAXMAX, MOST NONINTEGER AND WEIGHTED
                                                                     BOX10187
C NONINTEGER BRANCHING VARIABLE SELECTION RULES.
                                                                     BOX10188
                             290 IF (ITYPE.NE. 1) GOTO 320
                                                                     BOX10190
     IF ( IROUND. EQ. 0) GOT 0320
                                                                     BOX10191
C ROUND THE LOWER BOUND UP IF THE OBJECTIVE FUNCTION IS INTEGER VALUED. BOX10192
     IF (BOUNDL.LE. 0. 0) GOTO300
                                                                     BOX10193
     INTBD=BOUNDL + 1.0 + EPSIM
                                                                     BOX10194
     GOT0310
                                                                     BOX10195
 300 INTED=BOUNDL + EPSIM
                                                                     BOX10196
                                                                     BOX10197
  310 BOUNDL=INTBD
  320 IF ( KBRV . NE . 0 ) GOT 0 330
                                                                     BOX10198
     KBRV=JBRV
                                                                     BOX10199
      KUPD N= JUPDN
                                                                     BOX10200
C SELECT THE BRANCHING VARIABLE FOR A ONE PHASE METHOD OR PHASE 1 OF
                                                                     80X10201
C A THO PHASE METHOD.
                                                                     B0X10202
 330 GOTO(340,350,360,350,350),NBVRL1 + 1
                                                                     BOX10203
 340 IBRVR1= IBRV
                                                                     BOX10204
                                                                     BOX10205
     TUPON1 = 2
     G0T0370
                                                                     BOX10206
 350 IBR VR1=JBRV
                                                                     BOX10207
     IUP DN1 = JUPON
                                                                     B0X10208
                                                                     BOX10209
     GOT 0 37 0
 360 IBRVR1=KBRV
                                                                     BOX10210
     IUPDN1 = KUPDN
                                                                     BOX10211
 370 XBRVR1=0.0
                                                                     B0X10212
     IF (IBRVR1.NE.0) XBRVR1=XZ (IBRVR1)
                                                                     BOX10213
     IF (NSTRAT.EQ.1) GO TO 440
                                                                     BOX10214
C SELECT THE BRANCHING VARIABLE FOR PHASE 2 OF A TWO PHASE METHOD.
                                                                     80X10215
     GOTO (380,330,400,390,400) ,NBVRL2 + 1
                                                                     B0X10216
                                                                     BOX10217
 380 IBRVR2= IBRV
                                                                     BOX10218
     IUP CN2=2
     GOT0410
                                                                    BOX10219
 390 IBRVR2=JBRV
                                                                     BOX10220
                                                                     BOX10221
     IUPDN2=JUPDN
                                                                    BOX10222
     GOT 0410
 400 IBRVR2=KBRV
                                                                     BOX10223
     IUPONZ=KUPON
                                                                     BOX10224
                                                                    BOX10225
 410 XBRVR2=0.0
     IF (IBRVR2.NE.O) X BRVR2=XZ (IBRVR2)
                                                                     BOX10226
     GOT0440
                                                                    BOX10227
```



	CAVE NONLINEAR PROGRAM WITH THE CONVENTIONAL	80×10229
	NCHING VARIABLE SELECTION RULE.	BOX10 230

420	BOUNDU=Z	B0X10232
	PEN=0.0	B0X10233
	IBRVR1=0	B0X10234
	D0430I=1, M7	B0X10235
	IF(I.EQ.MP1)GOTO430	80X10236
	J=18V(I) IF(J.GT.N)GOTO430	B0X10237 B0X10238
	K=ICC(J) IF(K.EQ.0)GOTO430	B0X10239 B0X10240
	CALL GETOBJ (K, SIGMAL (J), FO)	B0X10241
	그 사람들이 아이들 것이 있다면 이 경험에 가장 되었다. 그렇게 되었다면 보다면 하는데 이번에 되었다면 하는데 되었다면 되었다면 하는데 되었다면 되었다면 되었다면 되었다면 되었다면 되었다면 되었다면 되었다면	80X10242
	CALL GETOBJ (K,XZ(J),F1) DELTA=F1 - (FG + C2(J)*(XZ(J)-SIGPAL(J)))	B0X10243
	BOUNDU=BOUNCU + DELTA	BOX10244
	IF (DELTA.LE.PEN)GOTO430	B0X10245
	PEN=DELTA	80x10246
	IBRVR1=J	B0X10247
430	CONTINUE	B0X10248
400	XBRVR1=0.0	B0X10249
	IF (IBRVR1.NE.0) XBFVR1=XZ (IBRVR1)	BOX10 250
	BOUNDL=Z	B0X19251
	IFEAS=1	B0X10252
C++++	***************************************	**************************************
C PRI	NT OUT THE RESULTS.	80X10254
	***************************************	**************************************
448	IF (IOUTPT.EQ. 0)GOTO540	B0X1025 €
	IF (NSTRAT.EQ.2 .AND. LPHASE.EQ.2)GOTO500	80X10257
	IF (IBRVR1.EQ.L) GO 10530	B0X10258
	IF(1.LE.NEVRL1 .AND. NBVRL1.LE.4)GOTO450	B0X10259
	WRITE(6,1000) IBRVR1	80×10 260
	G0T0470	BOX 10 26 1
450	IF (IUFDN1.EQ.2) GOTO460	B0X10262
	WRITE(6,1001)IBRV#1	B0X10263
	G0T0470	B0X10264
	WRITE(6,1002) IBRVR1	BOX10265
470	IF (NSTRAT.EQ.1) GOTO530	B0X10266
	IF (IERVR2.EQ.0)GOTO530	B0X10267
	IF (1.LE.NEVRL2 .AND. NBVRL2.LE.4) GOTO480	80X10268
	WRITE(6,1003) IBRVR2	B0X10269
Legan	G0T053C	B0X10270
400	IF (IUPDN2.EQ.2) GO 10490	B0X10271
	WRITE(6, 1004) IBRV 62	B0X10272
	6010530	80X10273
490	WRITE(6,1005)IBRVR2	B0X10274
	6010530	B0X10275
500	IF (IBRVR2.EQ.C)GOTO53C	B0X10276
	IF(1.LE.NBVRL2 .AND. NBVRL2.LE.4)GOTO510	80X10277
	WRITE(6,1000)IBRVF2	B0X10278
	G0T0530	B0X10279
510	IF (IUPDN2.EQ.2)GOTO 520	B0X10280
	WRITE(6,1001) IBRVR2	B0X10281
	G0T0530	B0X10282
	WRITE (6,1002) IBRVR2	BOX10283 BOX10284
534	MRITE (6, 1006) BOUNDL	80X10284
	IF (IFEAS.EQ. 1) WRI 1E (6, 1CO7) BOUNDU	eny10592

540 IF(NODE.NE.1 .OR. IBUROP.EQ.0)RETURN	B0X10286
C ESTABLISH THE INITIAL BEST UPPER BOUND.	B0X10287
UNOT=BOUNGL + PCBUB	B0X10288
IF(IOUTPT.NE.0)WRITE(6,1008)UNOT	B0X10289
RETURN	B0X10290
1000 FORMAT (10HOVARIABLE ,15,27H IS THE BRANCHING VARIABLE.)	B0X10291
1001 FORMAT (10HOVARIABLE , 15,69H IS THE BRANCHING VARIABLE. CONTINUE	BRB0X10292
1ANCHING FROM THE LOWER BRANCH.)	B0X10293
1002 FORMAT (10HO VARIABLE , 15,69H IS THE BRANCHING VARIABLE. CONTINUE	BRB0X10294
1ANCHING FROM THE UPPER BRANCH.)	B0X10295
1083 FORMAT (10HOV ARIABLE , 15, 39H IS THE BRANCHING VARIABLE FOR PHASE	2.80X1029E
1)	BOX10297
1004 FORMAT (10HOVARIABLE ,15,81H IS THE BRANCHING VARIABLE FOR PHASE	2.B0X10298
1 CONTINUE BRANCHING FROM THE LOWER BRANCH.)	B0X10299
1005 FORMAT (10HOVARIABLE , 15,81H IS THE BRANCHING VARIABLE FOR PHASE	2.80X10300
1 CONTINUE BRANCHING FROM THE UPPER BRANCH.)	BOX10301
1006 FORPAT(14H0LOHER BOUND =, E15.6)	B0X10302
1007 FORMAT(14HOUPPER BOUND = , £15.6)	B0X10303
1008 FORMAT (31HOTHE PHASE 1 BEST UPPER BOUND =,E15.6)	B0X10304
1089 FORMAT(11H *****BOX17)	BOX10305
ENO	B0X10306

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SUBROUTINE BOX23 (INUSE, XNOT, CAPP, XZ, ND1, ND6, ND10)
C UPDATE THE BEST UPPER BOUND. IF IN PHASE 1, MERGE THE SUBLIST INTO
                                                                                        BOX20 JC1
                                                                                        BOX23-62
C THE LIST AND ENTER PHASE 2. EDIT THE LIST.

COMMON/P1/N,M, ITYPE,NSTRAT,NODRL1,N3VRL1,NTITE1,NODRL2,NBVRL2,
                                                                                        BOX20CG3
                                                                                        BOX20004
                   NTITE2, MXLIST, LISTOP, IT APE, IF6, MXITER, MBINV, IOUTPT,
                                                                                        BOX20005
                   ITRACE, MSTART, TIME1, TOL1, TOL2, PC 8UB, ALPHA (1 )
                                                                                        BOXZULLE
       COMMON/P3/NODNOT, UNOT, IBUBOP, LPHASE, NODRUL, NBVRUL, NTIGHT, HLIST,
                                                                                        BOX20007
                   NLISTS, NFEAS, LSTHX, ITRTOT, ITRMAX, BLB, NBRNOD, PBRNOD,
                                                                                        B0X200G8
                   NBRVAR, NUPD HN, XBRNOD, TBRNOD, NODE, LNODE, Z, BOUNDL, BOUNDU,
                                                                                        BOX20209
                   TSIG, IFEAS, IBRVR1, IUPDN1, XBRVR1, IBRVR2, IUPDN2, XBRVR2,
                                                                                        BOX2JL1L
                   LIG, NITER, NOINY, MT, IPHASE, NPHASE, NM3M7, IALGO, IEOJ
                                                                                        BOX20511
                                                                                        B0X23012
       DIMENSION INUSE (ND18)
       DIMENSION XNOT (ND1), CAPF(ND10), XZ (ND6)
                                                                                        B0X20013
                                                                                        BOX 23 . 14
       IF(ITRACE.GE.1) HRITE(6, 1304)
C UPDATE THE BEST UPPER BOUND.
                                                                                        BOX20015
       NODNOT=NODE
                                                                                        BOX20016
       UNOT= BOUNDU
                                                                                        BOX20017
       D0130J=1,N
                                                                                        B0X23:18
  130 XNOT(J)=XZ(J)
                                                                                        BOX20019
C EDIT THE LIST.
                                                                                        BOX20020
       NDELET=J
                                                                                        BOX20021
       DO110I=1, HXLIST
                                                                                        B0X24-22
       IF (INUSE(I) .EQ.0) GOTO 113
                                                                                        B0X20523
       IF (CAPP(I).LT. (1.-TOL1) *UNOT) GOTO113
                                                                                        B0X20024
       INUSE (1) = 0
                                                                                        BOX20025
       NDELET=NDEL ET+1
                                                                                        BOX2J.26
  113 CONTINUE
                                                                                        B0X20327
                                                                                        B0X20028
       IF (IOUTPT.NE.0) WRITE(6, 1000) NODNOT, UNOT
       IF (NOELET.EQ. L) GOTO123
                                                                                        BOX20029
                                                                                        B0X20.36
       NLIST=NLIST-NOELET
                                                                                        B0X20031
       IF (IOUTPT.EQ. C) GOTO 126
                                                                                        BOX 20032
       WRITE (6,15J1) NOELET
       WRITE(6,1002)NLIST
                                                                                        BOX20033
  120 IF(ITYPE.EQ.2) RETURN
                                                                                        BOX26:34
       IF (LPHASE.EQ. 2) RETURN
                                                                                        BOX20035
C ENTER PHASE 2.
                                                                                        B0X20036
       LPHASE = 2
                                                                                        B0X20037
       IF (NSTRAT.EQ.1) GOTO130
                                                                                        BOX23. 38
       NODRUL = NODRL2
                                                                                        BOX20039
       NBVRUL = NBVRL2
                                                                                        BOX20040
       NTIGHT=NTITE2
                                                                                        BOX20041
  130 IF (IOUTPT.NE. 6) WRITE(6, 1983)
                                                                                        B0X23:42
       IF (IBUBOP. EQ. . ) RETURN
                                                                                        BOX20043
                                                                                        BOX20644
       IBUBOP=0
C MERGE THE SUBLIST INTO THE LIST.
                                                                                        BOX20045
                                                                                        BOX20-46
       DO140I=1, MXLIST
       IF (INUSE (I) . GE . . ) GOTO 14 .
                                                                                        BOX20047
       INUSE(I) = -I NUSE(I)
                                                                                        B0X20048
  140 CONTINUE
                                                                                        B0X20049
                                                                                        BOX20050
       RETURN
 1.3 FORMAT (6H. NODE ,15,35H FROVIDES THE NEW BEST UPPER BOUND ,615.6)
1001 FORMAT (46H. THE NUMBER OF NODES DELETED FROM THE LIST IS ,15)
1002 FORMAT (26H0THE CURRENT LIST SIZE IS ,15)
                                                                                        BOX 20651
                                                                                        B0X20052
                                                                                        BOX20053
 1003 FORMAT (14HOENTER PHASE 2)
                                                                                        BOX20.54
 1004 FORMAT (11H ***** BOX23)
                                                                                        BOX20055
       FND
                                                                                        BOX20356
```

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SUBROUTINE BOX25 (INUSE, IMS, C2, CAPP, CAPL, SIGMAL, SIGMAU, SLOLD,
                                                                         BOX20001
                                                                         BOX200G2
                        SUOLO, CZOLD, FMS, ND1, ND6, ND9, ND12, ND11, NDMS2,
                        NDM S3)
                                                                         BOX20003
G STORE NODE LNODE IN THE SUBLIST (WHEN IN PHASE 1 AND LOWER BOUND LESS BOX20164 C THAN BEST UPPER BOUND) OR IN THE LIST (OTHERWISE).
                                                                         BOX20005
      COMMON/P1/N, M, ITYPE, MSTRAT, NOORL1, NEVRL1, NTITE1, NOORL2, NBVRL2,
                                                                         B0X20306
                NTITE2, MXLIST, LISTOP, IT APE, IFB, MXITER, MOINV, IOUTPT,
                                                                         BOX20007
                ITRACE, MSTART, TIME1, TOL1, TOL2, PC BUB, ALPHA (13)
                                                                         B0X23108
      COMMON/P2/EPSI, EPSIM, BIGN, BEGTM, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2, BOX20009
                NM1M3, N1P2, NP1, NSUM, NTC, 41.
                                                                         BOX20010
      COMMON/P3/NCONOT, UNOT, IBUBOP, LPHASE, NODRUL, NBVRUL, NTIGHT, NLIST,
                                                                         BOX20011
                NLISTS, NFEAS, LSTMX, IT RTOT, ITRMAX, ELB, NBRNOU, PBRNOD,
                                                                         B0X23012
                NBRVAR, NUPD MN, XBRNOD, TBRNOD, NODE, LNODE, Z, BOUNDL, BOX20213
TSIG, IFEAS, IBRVP1, IUPON1, XBRVR1, IBRVR2, IUPDN2, XBRVR2, BOX20214
                L10, NITER, NBINV, N7, IPHASE, NPHASE, NM3M7, IALGO, IEOJ
                                                                         B0X20015
      (SZMCN) ZMI, (SIGN) 32UA I NOISMID
                                                                         BOX20016
                                                                         BOX20517
      DIMENSION CZ(ND1), CAPP(ND1.), CAPL (ND11), SIGMAL (ND6), SIGMAU(ND6),
                SLOLD(ND6), SUOLD(ND6), C20LD(ND9), FMS(NDMS3)
                                                                         BOX20018
                                                                         B0X23019
      IF(ITRACE.GE.1) WRITE(6, 1009)
C CHECK IF THE MAXIMUM LIST SIZE WILL BE EXCEEDED.
                                                                         BOX2 -- 2
      IF (NLIST+1.LE. MXLIST) GOTO:33
                                                                         BOX20021
      IF (IOUTPT.NE. &) WRITE(6, 1000) NODE
                                                                         B0X20522
C DETERMINE THAT NODE IN THE LIST WITH THE GREATEST LOWER BOUND.
                                                                         BOX20023
      GLB=-BIGN
                                                                         B0X20024
      DO133I=1, MXLIST
                                                                         BOX20025
      IF (INUSE(I) . EQ. . ) GOTO 100
                                                                         B0X20026
                                                                         BOX20.27
      IF (CAPP(I) . LE. GLB) GOTO133
      GLB=CAPP(I)
                                                                         BOX20128
      IO=I
                                                                         BOX20029
  140 CONTINUE
                                                                         B0X20330
      IF (30UNDL.LT.GLB) GOTO 113
                                                                         BOX 23 131
      IF (IOUTPT.EQ.C) RETURN
                                                                         BOX20:32
      WRITE (6,1001)
                                                                         BOX20033
      RETURN
                                                                         BOX20234
  110 IF (IOUTPT.NE. 0) WRITE (6, 1002) INUSE (10)
                                                                         BOX23:35
      IF(INUSE(IU).GE.0)GOTO120
                                                                         BOX20036
      NLISTS=NLISTS - 1
                                                                         BOX20037
  120 NLIST=NLIST - 1
                                                                         B0X20038
      INUSE (10) = 0
                                                                         BOX24.39
                                                                         BOX20240
      GOT 0150
C FINE AVAILABLE SPACE IN THE LIST.
                                                                         BOX20041
  130 D014310=1, MXLIST
                                                                         B0X20642
      IF (INUSE (ID) . EQ. 0) GOT 0150
                                                                         BOX 23: 43
  140 CONTINUE
                                                                         BOX20044
C STORE THE NODE IN THE SUBLIST.

BOX20.47
      INUSE (I) = - NODE
                                                                         BOX 20349
      NLISTS = NLISTS + 1
                                                                         BOX20150
      GOT0170
                                                                         BOX2..51
C STORE THE NODE IN THE LIST.
                                                                         B0X23053
160 INUSE (IJ) = NODE
                                                                         BOX20.55
                                                                         B0X20056
  176 NLIST=NLIST + 1
      IF(NLIST.GT.LSTMX)LSTMX=NLIST
                                                                         BOX23057
```

	IF(IOUTPT.E2.0)GOTO180	80x20058
	WRITE (6,1003) NODE	B0X20059
	WRITE (6,1004) NLIST	BOX50000
Ceee		19002XC8++++
C SE	T CAPP AND CAPL.	B0X20C62
		29002X0E****
C SE	T CAPP FOR THE NODE BEING SAVED.	80X20064
	CAPP(IQ)=BOUNDL	83X20065
	IF (NS TRAT . = 2 . 2) GOT 1190	B0X20066
	IF(NOORL1.E2.1)GOTO200	B0X20C67
	GOTO280	B0X20068
190	O IF(NOORL2.E3.1)GOTJ200	80X20C69
	IF(LPHASE.EQ.1 .AND. NOORL1.EQ.1) GOTO200	B0X20079
	GOT © 80	B0X20071
C DE	TERMINE CAPL FOR THE NODE BEING SIVED.	B0X20072
281	IF(1.LE.NBVRUL .AN). NBVRUL.LE.+)GOT)226	B0X20C73
	IF(LNODE.E2.2)30T0210	80X20074
	OCCUSED = OUNTED	B0X20075
	GOT0270	B0X20076
210	9 PNEWND=PBRNOD + 1.0	80X20077
	GOT0240	B0X20078
220	IF(LNODE.EQ. NUPDWN)GOTO23C	B0X20079
	OCVR89=CNH3NP	B0X20080
	GOT0270	B0X20081
230	PNEHND=PBRNOD + 1.0	B0X20082
241	0 IF(IBUBO - EQ. 0) GO TO 27 0	B3X20083
	PMIN=BIGN	B0X20084
	DO250 I=1. MXL IST	B0X20085
	IF(I.EQ.IC)3073250	B0X20086
	IF(INUSE(I).EQ.0)GOTO250	B0X20087
	IF(CAPL(I).LE.PBRNOD) GOTO253	83X20C88
	IF (CAPL (I) . JE. PMIN) GOTO 250	B3X20089
	PMIN=CAPL(I)	B0X20090
250	CONTINUE	80X20091
	IF(PMIN.ST.PNE4ND)SOTO270	B0X20092
C INC	CREPENT CAPL FOR NOCES SUBSEQUENT TO THE NODE BEING SAVED.	B0X20193
	00260 I=1, MXL IST	B0X20094
	IF(INUSE(I).EQ.2)GOTO26G	B0X20095
	IF(CAPL(I).LE.P3RNO)) GOTO250	80X20096
	CAPL(I) = CAPL(I) +1.3	B0X20097
260	CONTINUE	B0X20098
C SET	CAPL FOR THE NODE BEING SAVED.	80X20399
270	CAPL(IO)=PNEHNO	B0X20100
		****B0X20101
C WR	ITE OUT THE DATA FOR THIS NODE.	B0X20102
C+++		****B0X20103
280	IMS(1)=I9RVR1	B0X20104
	IMS(2)=IUPDN1	B0X20105
	IMS (3)=L10	B0X20106
	IMS(4)=NITER	B0X20107
	IMS(5)=NBINV	B0X20108
	IMS(6)=M7	B0X20109
	IMS(7)=IPHASE	B0X20110
	IMS (8)=NPHASE	B0X20111
	IMS(9)=NM3M7	B0X28112
	IF(NSTRAT.EG.1)GOTO290	B0X20113

```
INS(11)=IUPON2
                                                                          BOX20115
 290 FMS(1)=Z
                                                                          BOX20116
                                                                          BOX 20117
      FHS(2)=TSIG
      FMS(3) = XBRVR1
                                                                          BOX20118
      IF (NSTRAT.EQ. 1) GOTO363
                                                                          BOX20119
      FMS (4) = XBRVR2
                                                                          BOX20120
                                                                          BOX 20121
  333 IF (LNODE. EQ. 2) GOT 0335
C INTERCHANGE SIGMAL, SLOLD AND SIGMAU, SUOLD.
                                                                          BOX20122
      0031:J=1,N1P2
                                                                          BOX20123
      T1=SLOLD(J)
                                                                          B0X20124
      T2=SUOLD(J)
                                                                          BOX 2 12 5
                                                                          B0X20126
      SLOLD(J)=SIGMAL(J)
      SUOLD(J)=SIGMAU(J)
                                                                          BOX20127
      SIGMAL (J) =T1
                                                                          B0X20128
                                                                          BOX2-129
  310 SIGNAU(J) =T2
      IF(ITYPE.EQ.1) GOTO360
                                                                          BOX20130
C INTERCHANGE CZ AND CZOLO.
                                                                          BOX 20131
                                                                          BOX 20132
      0032.J=1,N
      TEMP=CZOLD(J)
                                                                          BOX20133
      C20LD(J)=C2(J)
                                                                          BOX 20134
  326 C2(J) = TEMP
                                                                          BOX 20135
      GOT0360
                                                                          BOX23136
C PUT SIGMAL INTO SLOLD, SIGMAU INTO SUOLD.
                                                                          BOX23137
  330 0034:J=1,N1P2
                                                                         BOX 20138
      SLOLD(J)=SIGMAL(J)
                                                                          B0X20139
  343 SUOLD(J)=SIGMAU(J)
                                                                          BOX24145
      IF (ITYPE.EQ.1) GOTO360
                                                                          B0X20141
C PUT CZ INTO CZOLD.
                                                                         BOX20142
      D0350J=1,N
                                                                          BOX20143
  351 C20LD(J)=C2(J)
                                                                          BOX2:144
  360 CALL HRITMS (2,IMS,NDMS2,IG)
CALL WRITMS (3,FMS,NDMS3,IJ)
                                                                         B0X20145
                                                                         BOX 20146
      IF (LNODE. EQ. 2) GOTO390
                                                                         B0X20147
C INTERCHANGE SIGNAL, SLCLD AND SIGNAU, SUOLD.
                                                                          B0X2J148
      D037JJ=1,N1P2
                                                                          BOX20149
      T1=SLOLD(J)
                                                                         BOX20150
      T2=SUOLD(J)
                                                                         BOX20151
      SLOLD(J)=SIGMAL(J)
                                                                         B0X23152
      SUOLD(J)=SIGMAU(J)
                                                                         BOX20153
      SIGMAL (J) =T1
                                                                         BOX23154
  370 SIGMAU(J) = T2
                                                                         BOX 20155
      IF(ITYPE.EQ.1) GOT0390
                                                                         BOX 20156
C INTERCHANGE CZ AND CZOLD.
                                                                          BOX20157
      D0383J=1.N
                                                                         BOX 20158
      TEMP=C2OLD(J)
                                                                         BOX20159
      C20LD (J) = C2(J)
                                                                         BOX 20 160
  380 C2(J) = TEMP
                                                                         BOX20161
C PRINT OUT THE LIST. B0X20163
  390 IF (IOUTPT.LE.2) RETURN
                                                                         BOX 20165
                                                                         BOX20166
      INDEX=0
      IF (NSTRAT.EQ. 2) GOTO40 J
                                                                         BOX2-167
      IF (NODRL1.EQ.1)GOTO425
                                                                         B0X20168
      GOT0410
                                                                         BOX20169
  430 IF (NODRL2.EQ. 1) GOTO420
                                                                         BOX20170
      IF (LPHASE.EQ.1 .AND. NOORL1.EQ. 1) GOTO42
                                                                         BOX20171
```

410	INDEX=1	B0X20172
	WRITE (6,1005)	BOX20173
	G0T0430	B0X20174
420.	WRITE (6,1006)	B0X2u175
430	D045.I=1, MXLIST	B0X20176
	IF(INUSE(I).EQ.0)GOTO450	B0X20177
	IF(INDEX.EQ.0) GOTO440	B0X20178
	WRITE (6,1007) INUSE(I), CAPP(I)	BOX 23179
	G0T0450	B0X2 J180
440	WRITE (6, 100 8) INUSE(I), CAPP(I), CAPL(I)	B0X20181
450	CONTINUE	B0X23182
	RETURN	B0X20183
1000	FORMAT (48HOLIST SIZE EXCEEDED WITH ATTEMPT TO RECORD NODE ,15)	B0X20184
1001	FORMAT (29H THE NODE IS NOT BEING SAVED.)	B0X2J185
1002	FORMAT (6H NODE ,15,31H IS BEING PURGED FROM THE LIST.)	BOX20186
1003	FORMAT (6H_NODE , 15,19H SAVED IN THE LIST.)	BOX 20187
1004	FORMAT (26HOTHE CURRENT LIST SIZE IS ,15)	B0X23168
1005	FORMAT (1H0, 3X, 4HNODE, 9X, 5HLOHER/17X, 5HBOUND//)	B0X2J189
1006	FORMAT (1HC, 3X, 4HNODE, 9X, 5HLOHER, 6X, 10HPROCESSING/17X, 5HBOUND,	BOX20190
	1 11x,5HORDER//)	BOX 20191
1007	FORMAT (3X, 15, 2X, E15.6)	B0X20192
1008	FORMAT (3X, I5, 2X, E15.6, 2X, F11.0)	BOX20193
1609	FORMAT (11H ***** BCX25)	80X20194
	END	BOX 20195

```
SUBROUTINE ADJUST (V1, V2, V3, V4, T1, T2, T3, T4, 3L, SU)
C ADJUST THE LOWER AND UPPER LIMITS ON A VARIABLE USING THE BEST
                                                                                    ADJU0061
                                                                                    SDDUUCOL
                                                                                    ADJUGGE 3
C UPPER BOUND.
       COMMON/P1/N,M, ITYPE, NSTRAT, NODRL1, NBVRL1, NTITE1, NODRL2, NBVRL2,
                                                                                    ADJUGGG4
                  NTITE2, MXLIST, LISTOP, ITAPE, IFB, MXITER, MEINV, IOUTPT, ITRACE, MSTART, TIME1, TOL1, TOL2, PC GUB, ALPHA (1 1)
                                                                                    ADJUDG05
                                                                                    ADJUG206
       COMMON/P3/NODNOT, UNOT, IBUBO?, LPHASE, NODRUL, NBVRUL, NTIGHT, NLIST,
                                                                                    ADJU3167
                  NLISTS, NFEAS, LSTMX, IT RTOT, ITRMAX, BLB, NBRNOD, PERNOD,
                                                                                    ADJUGGES
                  NBRV AR, NUPDWN, XBRNOO, YBRNOO, NODE, LNODE, Z, BOUNDL, BOUNDU, ADJUGGG
                  TSIG, IFEAS, IBRVR1, IUPDN1, XBRVR1, IBRVR2, IUPDN2, XBRVR2,
                                                                                    ADJU0016
                  L12, NITER, NBINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IEOJ
                                                                                    40JU-011
                                                                                    ADJU0312
       IF(ITRACE. GE. 2) WRITE(6, 1000)
C ASSUME THAT THE CURVE CONSISTS OF THO LINEAR SEGMENTS, ONE CONNECTING
                                                                                    ADJUJ013
C THE POINTS (V1,T1) AND (V2,T2), THE OTHER CONNECTING THE POINTS
                                                                                    ADJUD014
C (V3,T3) AND (V4,T4).
                                                                                    ADJU0315
                                                                                    ADJU0016
       SL=V1
       IF(T1.LE.UNOT) GOTO130
                                                                                    ADJU0317
                                                                                    ADJUJ: 18
       IF (T2.GE. UNOT) GOTO100
       SL=V2 + (UNOT - T2)+(V1 - V2)/(T1 - T2)
                                                                                    ADJU0019
       GOT0130
                                                                                    ADJU0020
                                                                                    ADJU0021
  133 IF (T3.GT.UNOT) GOTO110
       SL=V3
                                                                                    ADJUJ 22
       GOTO130
                                                                                    ADJU0023
  110 IF (T4.GE.UNOT) GOT0120
                                                                                    ADJUD024
       $L=V4 + (UNOT - T4)+(V3 - V4)/(T3 - T4)
                                                                                    ADJUJ025
       GOTO130
                                                                                    ADJUS: 26
                                                                                    ADJUGG27
  120 SL= V4
                                                                                    ADJU0028
  130 SU=V4
       IF (T4.LE.UNOT) RETURN
                                                                                    ADJUGC29
       IF (T3. GE. UNOT) GOTO140
                                                                                    ADJUG. 3.
       SU=V3 + (UNOT - T3)+(V3 - V4)/(T3 - T4)
                                                                                    ADJU0031
                                                                                    ADJU0032
       RETURN
                                                                                    ADJUD033
  140 IF (T2.GT.UNOT) GOTO150
       SU=V2
                                                                                    ADJUUJ34
       RETURN
                                                                                    ADJU0035
  150 IF (T1.GE. UNOT) GOTO160
                                                                                    ADJUDG36
                                                                                    ADJU0037
       SU=V1 + (UNOT - T1)*(V1 - V2)/(T1 - T2)
                                                                                    ADJUJ.38
       RETURN
  163 SU= V1
                                                                                    ADJU0039
                                                                                    ADJUSC46
       RETURN
 1000 FORMAT (12H *** ** ADJUST)
                                                                                    ADJU0041
                                                                                    ADJU0642
       END
```

```
SUBROUTINE BINVRT (NZ,NP,IR,IA,IS,IBV,NBV,IUPPER,TC,RHS,C2,C1,BI, BINVCC1
                            U,PJ,BINV,B,ND1, ND2, ND3, ND4, ND5, ND6, ND7)
                                                                                 BINVOCCZ
C COMPUTE THE BASIS INVERSE CORRESPONDING TO THE BASIS SPECIFIED
                                                                                 BINVOCOS
                                                                                 BINV3004
C IN AREAY IBV
      COMMON/P1/N, M, ITYFE, NSTRAT, NOORL1, NBVRL1, NTITE1, NOORL2, N& VRL2,
                                                                                 BINVOCOS
                  NTITE2, MXLIST, LISTOP, IT APE, IFB, MXITER, MOINV, IOUTPT,
                                                                                 BINVOCC6
                  ITRACE, MSTART, TIME1, TOL1, TOL2, PCBUB, ALPFA(10)
                                                                                 BINVCGG7
      COMMON/P2/EPSI, EPSIM. BIGN, BEGTM, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2,
                                                                                 BINVSCUB
                                                                                 BINVOCOS
                  NM1H3,N1P2,NP1,NSUM,NTC,M10
     1
      COMMON/P3/NODNOT, UNOT, IBUBOP, LPHASE, NODRUL, NBWRUL, NTIGHT, NLIST, NL ISTS, NFEAS, LSTMX, ITRT (T, ITRMAX, BLE, NBRNOD, PBRNOD,
                                                                                 HINVOC18
                                                                                 BINVOCAL
                  NBRVAR, NUPDHN, XERNOC, TBRNOD, NODE, LNODE, Z, BOUNDL, BCUNDU, BINVO 012
                  TSIG, IFEAS, IBRVR1, IUPDN1, XBRVR1, IBRVR2, IUFDN2, XBRVR2,
                                                                                 BINVOC13
                  L1G, NITER, NBINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IEOJ
                                                                                 BINVDC14
                                                                                 BINVOC15
      DIMENSION IS (ND4), I BY (ND4), NBY (ND5), IUPPER (ND5)
      DIMENSION BI (ND4) . U(ND6) . PJ(ND4) . B(ND4, ND4)
                                                                                 BINVOC16
      IF (ITRACE.GE.1) WRITE(6,1000)
                                                                                 BINVIC17
                                                                                 BINVOC18
C INITIALIZE THE BASIS MATRIX.
      D0100I=1, M7
                                                                                 BINVOC19
      DO 10 0 J= 1, M7
                                                                                 BINVJG25
  100 B(I,J)=0.0
                                                                                 BINVIC21
      D0139J=1, M7
                                                                                 SINVOCES
      KIND=IBV(J)
                                                                                 BINVICES
      D0110I=1.K7
                                                                                 BINVOUZ4
                                                                                 BINVOCES
  110 PJ(I)=0.0
      CALL GETCOL (NZ.NF, IR.IA, IS, TC, RHS, C2, C1, PJ.ND1, NC2, NO3, ND4, ND5,
                                                                                 BINVS:26
                                                                                 BINVCC27
                     KIND, NZEROS)
                                                                                 BINVOCZB
      DU120I1=1,NZEROS
                                                                                 BINVOCZ9
      I=IS(I1)
  120 B(I,J)=PJ(I)
                                                                                 BINVICES:
      B(MP1, J) = PJ(MP1)
                                                                                 BINVOC31
      IF (IPHASE.EQ.2) 8(MP2,J)=PJ(MP2)
                                                                                 BINVOLZE
                                                                                 BINVOL33
  133 CUNTINUE
C INITIALIZE THE RIGHT-FAND-SIDE, ADJUSTING FOR VARIABLES AT UPPER
                                                                                 BINVOC34
C BOUND IF NECESSARY.
                                                                                 31 NV3 ( 35
      NRH=N+H3+H7+1
                                                                                 BINVOLSE
      CALL GETCOL (NZ,NP, IR, IA, IS, TC, RHS, C2, C1, PJ, ND1, NC2, ND3, ND4, ND5,
                                                                                 BINVOL37
                                                                                 BINVILIB
     1
                     NRH, NZEROS)
      DO140J=1, H7
                                                                                 BINVOC39
  140 BI(J)=PJ(J)
                                                                                 BINV3C4C
                                                                                 BINVOC41
      D0170K=1,L10
      IF (IUPPER (K) .EQ.0 )GOT0170
                                                                                 B1 NV 3642
       INDEX=NBV (K)
                                                                                 BINVOC43
      D0150I=1.87
                                                                                 BINVIC44
                                                                                 BINVUL45
  150 PJ(1)=0.0
      CALL GETCOL (NZ,NP,IR,IA,IS,TC,RHS,C2,C1,PJ,NO1,NO2,NO3,NO4,NO5,
                                                                                 BINVOCAE
                     INCE X, NZEROS)
                                                                                 BINVOC47
      D016011=1,NZEROS
                                                                                 BINVJC48
                                                                                 BINVSC49
      I=15(I1)
  160 BI(I)=BI(I) - PJ(I)*U(INDEX)
                                                                                 BINVALSE
      BI(MP1)=BI(MP1) - PJ(MP1)*U(INDEX)
                                                                                 BINVOL51
      IF (IPHASE.EQ. 2) 81 (MP2)=81 (MP2) - PJ (MP2)+U(INDEX)
                                                                                 BINVILSE
                                                                                 BINVDD53
  170 CONTINUE
C OBTAIN THE BASIS INVERSE AND THE CORRESPONDING RIGHT-HAND-SIDE.
                                                                                 BINVOO54
      CALL INVERT (IS.BI.PJ.BINV.B.NO4.ND7)
                                                                                 BINVO055
      RE TURN
                                                                                 BINVOC56
 1600 FORHAT(12H *****BINVRT)
                                                                                 BINVO057
      END
                                                                                 BINVOCSE
```

```
SUBROUTINE GETCCL (NZ,NP.IR,IA,IS,TC,RHS,C2,C1,PJ,ND1,ND2,ND3,
                                                                                 GETC0001
ND4, ND5, J, NZER (S)
C GET THE J-TH COLUMN FROM THE CONSTRAINT MATRIX.
                                                                                 GE TCOOC 2
                                                                                 GETC0003
      COMMON/P1/N, M, ITYFE, NSTRAT, NOORL1, NBVRL1, NTITE1, NOORL2, NB VRL2,
                                                                                 GETC0024
                  NTITE2, MXLIST, LISTOP, IT APE, IFB, MXITER, MBINV, IOUTPT,
                                                                                 GETCGC05
                  ITRACE, PSTART, TIME1, TCL1, TOL2, PCBUB, ALPHA (10)
                                                                                 GETCOCC6
      COMMON/PZ/EPSI, EPSIM, BIGN, BEGTM, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2, GETCOCO7
                                                                                 GETCOCAB
                  NM1M3, N1P2, NP1, NSUM, NTC, M10
     1
      COMMON/P3/NOCNOT, UNOT, IBUBOP, LPFASE, NODRUL, NBVRUL, NTIGHT, NLIST,
                                                                                 GETCOCC9
                  NL ISTS, NEEAS, LSTMX, ITRT (T, ITRMAX, BL &, NBRNOD, PERNOD,
                                                                                 GETCOL13
     1
                  NBRVAR, NUPDHN, XBR NOD, TBRNOD, NODE, LNODE, Z, BOUNDL, BCUNDU, GETCO 611
     5
                  TSIG, IFEAS, IBRVR1, IUPDN1, XBRVR1, IBRVR2, IUFDN2, XBRVR2,
     3
                                                                                 GETC0012
                  L10, NITER, NBINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IECJ
                                                                                 GETC0013
      DIMENSION NZ (ND1), NP (ND1), IR (ND2), IA (ND2), IS (ND4)
                                                                                 GETC0014
       DIMENSION TC (ND3) ,RHS (ND4),C2 (ND1),C1 (ND5),PJ (ND4)
                                                                                 GETC3615
                                                                                 GETC0016
       IF (ITRACE.GE.2) WRITE(6,100)
                                                                                 GETCOC17
       IF (J.GT.N)GOTO110
                                                                                 GETCOC18
       NZEROS=NZ(J)
      NPOINT=NP(J)
                                                                                 GETCIL19
                                                                                 GETCOC2C
       DO1) JK=1, NZEROS
       NPOINT=NPOINT+1
                                                                                 GETCJC21
       I=IR (APOINT)
                                                                                 GEICOCZZ
                                                                                 GETC9023
       IS (K)=I
       INDEX=IA(NPOINT)
                                                                                 GETCOC24
  100 PJ(I)=TC(INDEX)
                                                                                 GETCOC25
      PJ (MP1) = C2(J)
                                                                                 GETCOC26
       IF (IPHASE . EQ . 2) PJ (MP2) = C1 (J)
                                                                                 GETC0027
                                                                                 GFTCCC28
       RETURN
  116 IF (J.GT.NF3) GOT 0120
                                                                                 GETCOC29
       J1=J-NM1M2
                                                                                 GETC0033
                                                                                 GETC3031
       NZEROS=1
                                                                                 GETC0:32
       IS(1)=J1
                                                                                 GETCOC33
       PJ(J1)=-1.0
       IF (IPHASE . EQ . 2)PJ (MP2) = C1(J)
                                                                                 GETC0634
                                                                                 GETC0035
       RE TURN
  126 IF (J.GT.NM3H7)GOT 013C
                                                                                 GETCSC36
       J1=J-NM3
                                                                                 GETC3C37
                                                                                 GETC0C38
       NZEROS=1
                                                                                 GETCOC39
       IS(1)=J1
                                                                                 GFTCCC40
       PJ(J1)=1.0
       RETURN
                                                                                 GETCD041
  130 D0140I=1.M
                                                                                 GETC0642
                                                                                 GETCOC43
  140 PJ(I)=RHS(I)
       PJ(MP1) =RHS(MP1)
                                                                                 GETC3044
       IF (IPHASE .EQ. 2) PJ (MP2)=RHS(MP2)
                                                                                 GETC0C45
                                                                                 GETCOL46
       RETURN
 1630 FORMAT (12H ****GETCOL)
                                                                                 GETCOC47
       END
                                                                                 GETCOC48
```

```
SUBROUTINE INPUT1 (NZ, NF, ND1)
                                                                                            INPUGGG1
C READ THE NUMBER OF LESS THAM, EQUALITY, GREATER THAM CONSTRAINTS. C READ THE NUMBER OF NONZERO ENTRIES BY COLUMN. DEVELOP THE COLUMN
                                                                                            INPUDGOZ
                                                                                            INPUGGO3
C POINTERS AND TOTAL STORAGE REQUIRED.
                                                                                            INPUGGG4
       COMMON/P1/N,M,ITYPE,NSTRAT,NODRL1,NSVRL1,NTITE1,NODRL2,NBVRL2,
NTITE2,MXLIST,LISTOP,ITAPE,IFB,MXITER,MBINV,IOUTPT,
                                                                                             INPUGCOS
                                                                                            INPUDGG6
                                                                                            INPUDGO7
      2
                    ITRACE, MSTART, TIME1, TOL1, TOL2, PC BUB, ALPHA (13)
                                                                                            INPUGICE
       COMMON/PZ/EPSI, EPSIH, BIGN, GEGTH, H1, M2, M3, M4, N1, MP1, MP2, NH3, NH1H2,
                    NH1M3, N1P2, NP1, NSUM, NTC, M10
                                                                                             INPUGGG9
                                                                                            INPUGG10
        DIMENSION NZ(ND1), NP(ND1)
       IF (ITRACE. GE. 1) WRITE(6, 10:4)
                                                                                            INPUDG11
                                                                                            INPUDG12
        READ(ITAPE, 1000) M1, M2, M3
        WRITE (6, 1001) M1, M2, M3
                                                                                            INPUGC13
       M4=M2+M3
                                                                                            INPUC:14
       N1=N+(H3+H1)+(H2+H3)
                                                                                            INPU0015
       MP1=M+1
                                                                                            INPU0316
        MP2=M+2
                                                                                            INPU0017
        NM3=N+M3
                                                                                             INPUDI18
        NH1H2=N-H1-H2
                                                                                            INPUDG19
       NM1 M3 = N+M1+M3
                                                                                            TNPU0020
        N1P2=N1+2
                                                                                            INPU0021
        NP1=N+1
                                                                                             INPULL 22
       READ(ITAPE, 10 0) (NZ(J), J=1,N)
WRITE(6,1802) (NZ(J), J=1,N)
                                                                                            INPU0023
                                                                                            INPUGG24
        NP(1)=0
                                                                                            INPUGG25
        00100J=2,N
                                                                                             INPULL 26
  139 NP(J) = NP(J-1) + NZ (J-1)
                                                                                            INPU0027
       NSUM=NP(N)+NZ(N)
                                                                                            INPUGG28
                                                                                            INPUBJ29
        PERCT = NSUM
        DENOM=H+N
                                                                                            INPUD:33
        PERCT=134. *PERCT/DENOM
                                                                                             INPUGG31
       WRITE (6,1833) NSUM, PERCT
                                                                                            INPUDD32
                                                                                            INPUDG33
        RETURN
 1000 FORMAT (1615)
                                                                                            INPUL:34
 1001 FORMAT (38 HO NUM BER OF CONSTRAINTS BY TYPE =,315) INPU0335
1002 FORMAT (38 HO NUM BER OF NONZERO ENTRIES BY COLUMN =,1615/(38X,1615)) INPU0036
                                                                                            INPUDU35
 1003 FORMAT (38HG TOTAL NUMBER OF NONZERO ENTRIES
                                                                                            INPUGG37
                                                                   =,I10,
 1 15H (A DENSITY OF ,F5.1,10H PERCENT).1
1004 FORMAT(12H *****INPUT1)
                                                                                            INPUGG38
                                                                                            INPUBB39
        END
                                                                                            INPUDDAG
```

```
SUBROUTINE INPUT2 (NZ,NP,IR,IA,ND1,ND2)
C READ THE CONSTRAINT MATRIX COLUMN-BY-COLUMN. IT IS ASSUMED THAT
C THE CONSTRAINTS ARE ORDERED (LESS THAN, EQUALITY, GREATER THAN
                                                                                                INPUJ_L1
                                                                                                INPUDGC2
                                                                                                INPUDDO3
                                                                                                INPUDIC4
C CONSTRAINTS).
        COMMON/P1/N,M, ITYPE, NSTRAT, NOORL1, N9VRL1, NTITE1, NOORL2, N8VRL2,
                                                                                                INPUL.15
                     NTITE2, MXLIST, LISTOP, ITAPE, IFB, MXITER, MBINV, IOUTPT, ITRACE, MSTART, TIME1, TOL1, TOL2, PC BUB, ALPHA (13)
                                                                                                INPUG.C6
       1
                                                                                                INPUDGO7
       2
        COMMON/P2/EPSI, EPSIM, BIGN, BEGTM, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2, INPUDUCA
                     NM1 M3, N1P2, NP1, NSUM, NTC, M1L
                                                                                                INPUJ.L9
        DIMENSION NZ(NO1), NP(NO1), IR(ND2), IA(ND2)
                                                                                                INPUDC10
                                                                                                INPUDG11
        IF(ITRACE.GE.1)WRITE(6,1003)
        D0100J=1,N
                                                                                                INPUDC12
        K1=NP(J)+1
                                                                                                INPUL.13
        K2=NP(J)+NZ(J)
                                                                                                INPUDD14
        READ(ITAPE, 1000) (IR(K), IA(K), K=K1, K2)
                                                                                                INPUDC15
   100 WRITE (6,1001) J, (IR(K), IA(K), K=K1, K2)
                                                                                                INPU0016
        READ (ITAPE, 1000) NTC
                                                                                                INPUD.17
        WRITE (6,1002) NTC
                                                                                                INPUGG18
                                                                                                INPUSO19
        RETURN
                                                                                                INPUJC20
 1000 FORMAT (1615)
 1001 FORMAT (8HGCOLUMN ,15,16H, ROW/CONSTANT =,1615/(29X,1615))
1002 FORMAT (22HD NUMBER OF CONSTANTS =,15)
                                                                                                INPUJ.21
                                                                                                INPUGG22
 1003 FORMAT (12H ***** INPUT2)
                                                                                                INPUDD23
                                                                                                INPU0024
        END
```

```
SUBROUTINE INPUTS (INT. ICC. NV.TC. BORIG, C2, SIGNAL, SIGNAU, V, ND1, ND3, INPUG 001
                                                                                INPUBD02
                            ND4, ND61
C READ THE TABLE OF CONSTANTS, THE RIGHT-HAND-SIDE, THE LOWER AND C UPPER BOUNDS, THE COST DATA, AND THE LISTS OF INTEGER AND CONCAVE
                                                                                INPUGGG 3
                                                                                INPUGGG4
                                                                                TNPHO 005
C VARIABLES
                                                                                INPUGGG 6
      COMMON/P1/N, H, ITYPE, NSTRAT, NODRL1, NBVRL1, NTITE1, NODRL2, NBVRL2,
                                                                                INPUGGG7
                 NTITE2. MXLIST, LISTOP, ITAPE, IF8. MX ITER. MBINV, IOUTPT.
     2
                  ITRACE, HSTART, TIME1, TOL1, TOL2, PCBUB, ALPHA(10)
                                                                                INPUGGO8
                                                                                INPUG 009
      COMMON/P2/EPSI, EPSIM, BIGN, BEGTM, M1, M2, M3, M4, N1, MP1, MP2, MM3, NM1M2,
                 NH1H3, N1P2, NP1, NSUM, NTC, M10
                                                                                TNPU0010
                                                                                INPUD011
      COMMON/PS/IROUND
      DIMENSION INT(NO1), ICC(NO1), NV(NO6)
                                                                                INPU0012
      DIMENSION TC (ND3), BORIG (ND4), C2 (ND1), SIGMAL (ND6), SIGMAU(ND6),
                                                                                INPU0013
                                                                                INPU0014
                 V (ND6)
      DATA BIGINT/1.0E+14/
                                                                                INPUGG15
      IF (ITRACE.GE.1) WRITE (6,1014)
                                                                                INPUDG16
C READ THE TABLE OF CONSTANTS AND THE RIGHT-HAND-SIDES. IT IS ASSUMED
                                                                                INPUGG17
                                                                                THPURG 18
C THAT THE RIGHT-HAND-SIDES ARE NONNEGATIVE.
      READ (ITAPE. 1001) (TC(K), K=1, NTC)
                                                                                INPU0019
      READ(ITAPE, 1601) (BORIG(I), I=1, H)
                                                                                INPU0020
                                                                                INPU0021
      IF( ITAPE.NE. 5) REWIND ITAPE
                                                                                INPUD022
      BORIG(MP1)=0.0
                                                                                INPU0023
      WRITE(6,1002)(TC(K),K=1,NTC)
      WRITE(5,1003) (BORIG(I), I=1, H)
                                                                                INPU0024
                                                                                INPUGG25
C READ LOWER AND UPPER BOUNDS ON THE VARIABLES.
      D0100J=1,N1P2
                                                                                TNPUB026
                                                                                INPUGG27
      SIGHAL(J)=0.0
  100 SIGNAU(J)=BIGN
                                                                                INPU0028
                                                                                INPUDD29
      READ(5, 1000) NON
                                                                                TNPU0030
      WRITE(6, 1004) NON
                                                                                INPU0031
      IFINDN. EQ. 0) GOT 0120
      READ(5, 1000) (NV(K),K=1, NDN)
                                                                                INPU0032
                                                                                INPU0033
      READ(5, 1001) (V(K), K=1, NON)
                                                                                TNPUB034
      WRITE(5,1005)(NV(K),K=1,NON)
      WRITE(5, 1006) (V(K),K=1, NDN)
                                                                                INPU0035
                                                                                INPU0036
      D0110<=1.NDN
                                                                                INPU0037
      J=NV(K)
                                                                                INPU0038
  110 SIGMAL(J)=V(K)
                                                                                INPU0039
  120 READ(5, 1600) NUP
                                                                                INPU0040
      WRITE(5,1007)NUP
                                                                                INPUD041
      IF(NUP. EQ. 0) GOT 0140
                                                                                INPUDD42
      READ(5, 1000) (NV(K),K=1, NUP)
      READ(5, 1001) (V(K),K=1,NUP)
                                                                                INPUGG43
      WRITE(5,1005) (NV(K),K=1,NUP)
                                                                                INPU0044
                                                                                INPUDO45
      WRITE(5,1008) (V(K),K=1,NUP)
      00130K=1,NUP
                                                                                INPUDD46
                                                                                INPU0047
      J=NV(K)
                                                                                INPU0048
  130 SIGHAU(J)=V(K)
                                                                                INPUGG49
C READ COST DATA.
  140 READ (5, 1001) (C2 (J), J=1, N)
                                                                                INPUGG50
      WRITE(5,1009) (C2(J),J=1,N)
                                                                                INPU0051
                                                                                INPUG052
      00150J=1,N
  150 INT(J)=0
                                                                                INPUGG53
      IF(ITYPE.EQ.2 .OR. ITYPE.EQ.3)GOT0170
                                                                                INPUDD54
C READ THE LIST OF INTEGER VARIABLES.
                                                                                INPUD055
      READ(5, 1000) NINT
                                                                                INPUGOS6
                                                                                INPUGG57
      READ(5, 1000) (NV(K), K=1, NINT)
```

```
WRITE(6,1010)NINT
                                                                              INPUDO58
                                                                              INPUG059
      WRITE(5,1011) (NV(K),K=1,NINT)
                                                                              INPUGG60
      DO1 60<=1.NI NT
      J=NV (K)
                                                                              INPUGG61
                                                                              INPU0062
      INT(J)=K
                                                                              INPUDO63
      IF (SIGNAU(J) .LE. BIGINT) GOTO 160
                                                                             TNPHIDG64
      SIGHAU(J)=BIGINT
  160 CONTINUE
                                                                              INPUDD65
  170 DO180J=1.N
                                                                              INPUDO66
                                                                              INPUGG67
  180 ICC(J)=0
      IFCITYPE.EQ.1 .OR. ITYPE.EQ.31GOTO200
                                                                              INPUDD68
C READ THE LIST OF CONGAVE VARIABLES.
                                                                              INPUGG69
      READ (5, 1000) NCC
                                                                              INPU0.070
                                                                             TNPUB071
      READ(5, 1000) (NV(K),K=1,NCC)
                                                                             INPU0072
      WRITE(6,1012)NCC
      WRITE(5,1013) (NV(K),K=1,NCC)
                                                                              INPU0073
      D0190<=1,NCC
                                                                             INPUGC74
                                                                              INPUDO75
      J=NV(K)
                                                                              TNPU0076
  190 ICC(J)=K
  200 IF (ITY PE.NE. 1) RETURN
                                                                              INPUBO77
C FOR THE MIXED INTEGER LINEAR PROGRAM, DETERMINE IF THE OBJECTIVE
                                                                              INPUGG78
C FUNCTION IS INTEGER VALUED.
                                                                             INPUGO79
                                                                              TNPUDDAG
      IROUND=0
                                                                              INPU0081
      D0220J=1,N
      IF (INT ( J) . NE . 0) GO TO210
                                                                              INPUDU82
      IF(C2(J) .NE.O.O) RETURN
                                                                              INPUO083
                                                                              TNPUON84
      GOTO220
  210 IC2=C2(J)
                                                                              INPUGG85
      FC2=IC2
                                                                              INPUGG86
      IF (C2(J) . NE. FC2) RETURN
                                                                             INPUGG87
  220 CONTINJE
                                                                             INPUGG88
      IROUND=1
                                                                              INPUGG89
                                                                              INPUDO90
      RETURN
                                                                             INPU0091
 1000 FORMAT(1615)
                                                                             INPUG092
 1001 FORMAT(6E12.0)
1002 FORMAT(22HOTABLE OF CONSTANTS =, 6E15.6/(22X, 6E15.6))
                                                                             INPU0093
 1003 FORMATI 22HOR IGHT -HAND-SIDE
                                     =,6E15.6/(22X,6E15.6))
                                                                             INPUGG94
 1004 FORMAT (42HO NUMBER OF VARIABLES HAVING LOWER BOUNDS =, 15)
                                                                             INPUG095
                               =,16I5/(22X,16I5))
1005 FORMAT (22HOVARIABLES
                                                                             TNPUBA96
 1006 FORMATIZZHOLOWER EOUNDS
                                       =,6E15.6/(22X,6E15.6))
                                                                             INPU0097
 1007 FORMAT(42HO NUMBER OF VARIABLES HAVING UPPER BOUNDS =, 15)
                                                                             INPU0098
1008 FORMAT(22HOUPPER BOUNDS
1009 FORMAT(22HOCOST COEFFICIENTS
                                     =,6E15.6/(22X,6E15.6))
=,6E15.6/(22X,6E15.6))
                                                                             INPUD099
                                                                             INPU0100
 1010 FORMAT(30HO NUMBER OF INTEGER VARIABLES =, 15)
                                                                             INPU0101
 1011 FORMATICZHOINTEGER VARIABLES
                                     =,1615/(22X,1615))
                                                                             INPU0102
1012 FORMAT (30HO NUMBER OF CONCAVE VARIABLES =, 15)
                                                                             INPU0103
 1813 FORMAT (22H) CONCAVE VARIABLES
                                                                             INPUG104
                                       =,1615/(22X,1615))
                                                                             INPU0105
 1014 FORHAT(12H *****INPUT3)
      END .
                                                                              INPU0106
```

```
SUBROUTINE INPUT4 (NZ,NP,IR,IA,IS,NV,IBV,NBV,IUPPER,TC,BORIG,RMS, INPUBOD1
                                                                             INPUDDO2
                          C2,C1,BI,BN,L,PJ,BINV,B,ND1,ND2,ND3,ND4,ND5,
                                                                             INPUGGG3
     2
                          ND6, ND7)
                                                                            INPUDOD4
C ESTABLISH THE INITIAL BASIS, BASIS INVERSE, AND RIGHT-HAND-SIDE FOR
                                                                             INPUGGO 5
C THE LP.
                                                                             INPUDDDE
      COMMON/P1/N, M, ITYFE, NSTRAT, NO [R L1, NBVRL1, NTITE1, NODRL2, NBVRL2,
                 NTITE2. MXLIST, LISTOP, ITAPE, IFB, MXITER, MBINV, IOUTPT,
                                                                             INPUDDO7
                 ITRACE, MSTART, TIME1, TOL1, TOL2, PCBUB, ALPHA(10)
                                                                             INPUDDOS
     2
      COMMON/P2/EPSI, EPSIH, BIGN, BEGTH, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2, INPU0009
                                                                             INPUDG10
                 NM1M3, N1P2, NP1, NSUM, NTC, M10
      COMMON/P3/NOONGT, UNOT, I EUBOP, LP FASE, NODRUL, NBVRUL, NTIGHT, NLIST,
                                                                             INPUGG11
                 NLISTS, NFEAS, LSTMX, ITRT CT, ITRMAX, BLB, NBRNOD, PBRNOD,
                                                                             INPUDG12
                 NBRVAR, NUPC NN, XBRNOO, TBRNOO, NODE, LNODE, Z, BOUNDL, BCUNDU, INPUCC13
     2
                 TSIG, IFEAS, IBRVR1, IUPDN 1, XBRV F1, IBRVR2, IUFQN2, XBRVR2,
                                                                             INPUDC14
                 L10, NITER, NBINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IEOJ
                                                                             INPUDD15
      DIMENSION NV (ND6), IBV (ND4), NBV (ND5), TUPPER (ND5)
                                                                             INPUGG16
      DIMENSION BI (ND4) ,BN(ND5) ,U(ND6) , FJ(ND4) ,B(ND4, ND4)
                                                                             INPUGG17
                                                                             INPUCC18
      IF (ITRACE.GE.1) WRITE(6,1003)
                                                                             INPUDG19
C READ INITIAL FEASIBLE BASIS. INITIALIZE PARAMETERS USED IN LP.
                                                                             INPUDD20
      L10=N1-M
      DO100I=1.L10
                                                                             INPUDD21
                                                                             INPUDC22
      IUPPER(I)=0
  100 BN(I)=0.0
                                                                             INPUDD23
                                                                             INPU0024
      IF (IF8.EQ.0) GOTO210
C INITIAL FEASIBLE BASIS PROVIDED AS INFUT.
                                                                            INPUDD26
      READ(5, 1000) (IBV(I), I=1, M)
      IF (M4.EQ. 0) GOT013C
                                                                             INPUDD27
      D0110I=1,M
                                                                             INPUC028
                                                                             INPUDG29
      IF (IBV(I).GT.NM1M3)GOTO120
                                                                             INPUDO30
  110 CONTINUE
                                                                             INPUGG31
      GOT0130
C THERE ARE ARTIFICIAL VARIABLES IN THE INITIAL BASIS.
                                                                             INPU0032
                                                                             INPU0033
  120 IBV(MP1)=N1+1
                                                                             INPU0034
      IBV(HP2)=N1P2
      M7=MP2
                                                                             INPUDO35
                                                                             INPUGG 36
      IPHASE= 2
      NPHASE= 1
      CALL OBJ1 (NZ,NP,IR,IA,IS,IBV,TC,BORIG,RHS,C1,NO1,ND2,ND3,NO4,ND5)INPUDC38
      GOTO 140
                                                                             INPUDD39
C THERE ARE NO ARTIFICIAL VARIABLES IN THE INITIAL BASIS.
  130 IBV(MP1)=N1+1
                                                                             INPUGG41
                                                                             INPUDG42
      H7=HP1
                                                                             INPUDO43
      IPHASE=1
      NPHASE= 0
                                                                             INPUDG44
  140 WRITE(6,1001)(IBV(I), I=1, M7)
                                                                             INPUDD45
                                                                             INPUDD46
C FORM THE LIST OF NON-EASIC VARIABLES.
      INDEX=0
                                                                             INPUDG67
                                                                             INPUDD48
      DO16 0K= 1, NM1 M3
      D0150I=1, M
                                                                             IHPU0049
      IF (K.EQ. IBV(I)) GOT 0160
                                                                             INPUDO50
                                                                             INPU0051
  150 CONTINUE
      INDEX=INDEX+1
                                                                             INPUD052
                                                                             INPUDO53
      NBV(INDEX)=K
                                                                             INPUGG54
  160 CONTINUE
      L10= INDEX
                                                                             INPU0055
C REAL NON-BASIC VARIABLES INITIALLY AT UPPER BOUND.
                                                                             INPUDO56
                                                                             INPUGES7
      READ (5. 1000 ) NUP
```

```
INPUGGS 8
      IF (NUP. EQ. 0) GOTO206
                                                                                INPU0059
      READ (5, 1000) (NV (K) ,K=1, NUP)
      WRITE(6, 1362) (NV(K) ,K=1,NUP)
                                                                                INPUDGED
                                                                                INPUDC61
      DO1 90K= 1, NUP
                                                                                INPUGG62
      INDEX=NV(K)
                                                                                INPUGG63
      D0170I=1.L10
                                                                                INPUDC64
      IF (NBV(I) .EQ. INDEX) GOTO 180
                                                                                INPUCC65
  176 CONTINUE
                                                                                INPUDG66
  180 IUPPER(I)=1
      BN(I)=U(INDEX)
                                                                                INPUBC67
  196 CONTINUE
                                                                                INPUDD68
                                                                                INPUDD69
  200 CONTINUE
C FORM THE BASIS INVERSE AND INITIALIZE THE RIGHT-HAND-SIDE.
                                                                                INPUDE75
      NM3M7=N+M3+M7
                                                                                INPUSC71
      CALL 81NVRT (NZ,NF,1R,1A,1S,18V,NBV,1UPPER,TC,RHS,C2,C1,81,U,PJ,61NV,8,ND1,ND2,ND3,N14,ND5,ND6,ND7)
                                                                                INPUDC72
                                                                                INPUCL73
     1
H10=H7
                                                                                INPUGL74
      IEOJ=0
                                                                                INPUCC 75
                                                                                INPUDE76
      NITER=0
                                                                                INPUDC77
      NBINV=3
                                                                                INPUDG78
      RETURN
C INITIAL FEASIBLE BASIS NOT PROVIDED AS INPUT.
                                                                                INPUSU79
  210 IF (M4.EQ.0) GOTO236
                                                                                INPUDC80
                                                                                INPUDD81
      M7=HP2
                                                                                INPUDE 82
      LIMIT=N+M3+1
      JCOUNT=N1P2
                                                                                INPUDL83
                                                                                INPUCC84
      K=0
                                                                                INPUCC85
      DOZZOI=LIMIT, JCCUNT
                                                                                TNPU0386
      K=K+1
  220 IBV(K)=I
                                                                                INPUCC 87
                                                                                INPUDESS
      IPHASE=2
                                                                                INPUGG89
      NPHASE= 1
      CALL OBJ1 (NZ,NP,IR,IA,IS,IBV,TC,EORIG,RHS,C1,ND1,ND2,ND3,NO4,NO5)INPUCGGC
      G010250
                                                                                INPUBC91
                                                                                INPUDE 92
  230 M7=MP1
                                                                                INPUDE93
      LIMIT=N+M3+1
      JCOUNT=N1+1
                                                                                INPUDG94
                                                                                INPUDG95
                                                                                INPUDC 96
      DO24 GI=LIMIT, JCOUNT
                                                                                INPUDE97
      K=K+1
  240 18V(K)=I
                                                                                INPUDG98
      IPHASE=1
                                                                                INPUGG 99
                                                                                INPUS 100
      NPHASE=U
  250 IF (IOUTPT.GE.3) WRITE(6,1001) (IBV(I), I=1, M7)
                                                                                INPUSIG1
                                                                                INPUDIG2
      D0260I=1,L10
                                                                                INPU0163
  260 NBV(I)=I
                                                                                INPUBLC4
      NM3M7=N+M3+M7
      D0270 I=1, M7
                                                                                INPUDIOS
                                                                                INPUDIO 6
      DU270J=1, M7
  270 B(I, J)=0.0
                                                                                INPUDIO7
      DO 28 0K=1, M7
                                                                                INPUDID8
                                                                                INPU0109
  280 B(K, K)=1.0
                                                                                INPUG 116
      NRH=N+H3+H7+1
      CALL GETCOL (NZ,NP, IR, IA, IS,TC,RHS,C2,C1,PJ,ND1,ND2,ND3,ND4,ND5,
                                                                               INPU0111
                                                                                INPUO112
                    NRH, NZEROS)
                                                                                INPU0113
      D0290J=1,H7
                                                                                INPUG114
  290 BI (J)=PJ(J)
```

	M10=M7	INPUG115
	IEOJ=0	INPUB116
	NITER=0	INPUBLIT
	NBI NV= C	INPU0118
	RETURN	INPUDI19
1000	FORMAT (1615)	INPUG120
1001	FORMAT (25HO INITIAL FEASIBLE BASIS =,1615/(25X,1615))	INPUJ121
1002	FORMAT (37HO NON-BASIC VARIABLES AT UPPER BOUND =,1615/(37X,1615))	INPUG122
	FORMAT (12H ***** INPUT4)	INPUG123
	END	INPUJ124

```
SUBROUTINE INPUTS (NZ,NP,IR,IA,IS,IBV,NBV,IUPPER,TC,RHS,C2,C1,BI, INPUDIC1
                           U, PJ, 8, NO1, NU2, NO3, ND4, ND5, ND6)
                                                                                 INPUDGE2
                                                                                 INPUGLE3
C DETERMINE THE APPLICABLE LP ALGORITHM.
      COMMON/PI/N,M, ITYPE, NSTRAT, NODRL1, NBVRL1, NTITE1, NODRL2, NBVRL2,
                                                                                 INPUGGC4
                                                                                 INPUBCO 5
                 NTITE2, MXLIST, LISTOP, IT APE, IFB, MXITER, MBINV, IOUTPT,
                  ITRACE, MSTART, TIME1, TOL1, TOL2, PCBLB, ALPHA (13)
                                                                                 INPUSCC6
                                                                                INPUDGG7
      COMMON/P2/EPSI, :PSIM, 81GN, 81GTM, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2,
                 NM1M3, N1P2, NP1, NSUM, NTC, M1.
                                                                                 INPUGD08
      COMMON/P3/NODNOT, UNOT, I BUBOP, LPHASE, NODRUL, NBVRUL, NTIGHT, NLIST,
                                                                                 INPUBCE9
                  NLISTS, NFEAS, LSTMX, ITRTOT, ITRNAX, BLB, NBRNOD, PBRNOD,
                                                                                 INPUDG10
                  NERVAR, NUPDWN, XERNOD, TERNOD, NODE, L NODE, Z, SOUNDL, BOUNDU, INPUGG11
                  TSIG, IFEAS, IBRVR1, IUPON1, XBKVR1, IBRVR2, IUPON2, XBRVR2,
                                                                                 INPUJ: 12
                  L10, NITER, NBINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IEOJ
                                                                                 INPUGG13
      DIMENSION IS(NO4), IBV (NO4), NBV (ND5), TUPPER (ND5)
                                                                                 INPUDC14
      DIMENSION BI(NO4), U(NO6), PJ(NO4), B(ND4, NO4)
                                                                                 INPUG.15
                                                                                 INPUDC16
      IF (ITRACE.GE.1) WRITE(6, 1316)
                                                                                 INPUGG17
C SHECK PRIMAL FEASIBILITY.
      IPRIM= 0
                                                                                 INPUDC18
                                                                                 INPUS.19
      00133I=1, M
      IF (BI (I) .LT .EPSIM) GOT 0120
                                                                                 INPU0 020
                                                                                 INPUG021
  130 CONTINUE
      D0110 I=1, M
                                                                                 INPUDG22
      I1= I8V(I)
                                                                                 INPUDJ23
                                                                                 INPU._24
      IF (U(I1)-8I(I) .LT.EPSIM)GOT3120
                                                                                 INPUDD25
  113 CONTINUE
                                                                                 INPUDG26
      IPRIM=1
  120 CONTINUE
                                                                                 INPUDD27
                                                                                 INPUDG28
C CHECK DUAL FEASIBILITY.
      IDUAL = 0
                                                                                 INPUDG29
                                                                                 INPUDG30
      D015. I POS=1,L10
      KIND=NBV(IPOS)
                                                                                 INPUL.31
                                                                                 INPU0032
      D0130I=1, H7
  130 PJ(I)=0.0
                                                                                 INPUGO33
                                                                                 INPUDO34
      CALL GETCOL (NZ,NP, IR, IA, IS, TC, RHS, CZ, C1, PJ, ND1, ND2, ND3, ND4, ND5,
                                                                                 INPUJ:35
                     KIND, NZEROS)
      Q1=3.0
                                                                                 INPUGG36
      00143J1=1, NZEROS
                                                                                 INPUDG37
                                                                                 INPUGG38
      J=IS(J1)
                                                                                 INPU. 39
  140 Q1=Q1 + B(MP1, J) *PJ(J)
      Q1=Q1 + B(MP1, MP1) +PJ(MP1)
                                                                                 INPUSS40
      IF (IPHASE.EQ. 2)Q1=Q1 + 8(HP1, HP2) +PJ(HP2)
                                                                                 INPU0041
      IF(IUPPER(IPOS).EQ. 1) Q1 =-Q1
                                                                                 INPU0042
                                                                                 INPUS.43
      IF(Q1.LT.EPSIM)GOTO160
  153 CONTINUE
                                                                                 INPUDG44
                                                                                 INPUCC45
      IDUAL=1
                                                                                 INPUDD46
  160 CONTINUE
C SELECT THE ALGORITHM TO BE USED.
                                                                                 INPUDD47
                                                                                 INPUGG48
      IF (IOUTPT.LE. 2) GOTO17
       IF (IPHASE.EQ. 2) WRITE(6, 1000)
                                                                                 INPUGG49
                                                                                 INPUGG50
      IF (IPHASE.EQ. 1) WRITE(6, 1001)
                                                                                 INPU0 351
  170 IF (IPRIM. EQ. J) GOTO193
                                                                                 INPUGG52
      IF (IOUTPT.LE.2)GOTO18.
                                                                                 INPUD053
      WRITE (6, 1002)
                                                                                 INPUDO54
      IF (IPHASE. EQ. 2) WRITE(6, 1306)
                                                                                 INPUGG55
      IF(IPHASE.EQ.1) WRITE(6, 1007)
                                                                                 INPUC:56
  180 IALGO=1
      RETURN
                                                                                 INPUGUS7
```

	190	IF (ICUTPT.LE.2)GOTO200 WRITE (6,1003)	INPUDD58
			INPU0059
	200	IF(IDUAL.EQ.0)GOTO220	INPUDION
		1, (1001)1, (2010)10510	INPUGG61
		WRITE(6,1004)	INPUGO62
		WRITE(6,1008)	INPUDG63
	210	IALGO=2	INPUL.64
		IF(IPHASE.EQ.1)RETURN	INPUDC65
		NPHASE = 2-	INPUDG66
		M10=MP1	INPUJC67
		RETURN	INPULL 68
	220	1F(IOUTPT.LE.2)G0T0230	INPUGG69
		WRITE (6,1005)	INPUG 070
		WRITE (6.1009)	INPUGO71
	230	IALGO=0	INPUL. 72
	-	RETURN	INPUDO73
1	000	FORMAT (44HOTHERE ARE ARTIFICIALS IN THE INITIAL BASIS.)	INPUGG74
		FORMAT (47HOTHERE ARE NO ARTIFICIALS IN THE INITIAL BASIS.)	INPUDO75
		FORMAT (38H THE INITIAL EASIS IS PRIMAL FEASIBLE.)	INPU2.76
		FORMAT (42H THE INITIAL BASIS IS NOT PRIMAL FEASIBLE.)	INPUGG77
		FORMAT (36H THE INITIAL BASIS IS DUAL FEASIBLE.)	INPU0378
		FORMAT (40H THE INITIAL BASIS IS NOT DUAL FEASIBLE.)	INPU0079
		FORMAT (54H THE PRIMAL ALGORITHM (THO PHASE METHOD) WILL BE USED.)	INPUJ080
		FORMAT (54H THE PRIMAL ALGORITHM (ONE PHASE METHOD) WILL BE USED.)	INPU0081
		FORMAT (41H THE DUAL SIMPLEX ALGORITHM WILL BE USED.)	INPU0082
1	009	FORMAT 164H NEITHER THE PRIMAL NOR THE DUAL SIMPLEX ALGORITHMS CAN	INPU0983
		LOE USED.)	INPUGG84
1	110	FORMAT (12H *****INPUT5)	INPUGG85
		END	INPUDD86

```
SUBROUTINE INVERT (IS,81,FJ,81NV,8,ND4,ND7)
C GAUSS-JORDAN METHOD OF MATRIX INVERSION.
                                                                                           INVEOGO 1
                                                                                           INVEDCOZ
       COMMON/P1/N, M, ITYPE, NSTRAT, NOCRL1, N3VRL1, NTITE1, NOORL2, NB VRL2,
                                                                                           THVFOC03
                    NTITE2, MXLIST, LISTOP, ITAPE, IF3, MXITER, MAINV, 100 TPT, ITRACE, MSTART, TIME1, TOL1, TOL2, PCBUB, ALPHA (10)
                                                                                           INVEDCO4
                                                                                           INVEDODS
       COMMON/P2/EPSI, EPSIM, BIGN, BEGTM, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2, NM1M3, N 1P2, NP1, NSUM, NTC, M10
COMMON/P3/NODNOT, UNOT, IBUBOF, LPHASE, NODRUL, NBVRUL, NTIGHT, NLIST,
                                                                                          INVEDDU6
                                                                                           TNVFOGGT
                                                                                           INVESTUB
                    NLISTS, AFEAS, LSTMX, ITRTCT, ITRMAX, BLE, ABRNOD, PBRNOC,
                                                                                           INVEDCO9
                    NBRVAR, NUPDHN, X BRNOD, TBFNOD, NODE, LNODE, Z, BOUNDL, BCUNDU, INVE 0 0 1 0 TSIG, IF EAS, IBRVR1, IUPON1, XBRVR1, IBRVR2, IUPON2, XBRVR2, INVE 0 C11
                    L10, NITER, NBINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IECJ
                                                                                           INVECC12
       DIMENSION IS (ND4)
                                                                                           INVECC13
       DIMENSION BI (NO4) ,PJ (NO4) ,BINV (NO7, NO7) ,B (NO4, ND4)
                                                                                           INVEDC14
       IF (ITRACE.GE. 1) WRITE (6, 1001)
                                                                                           INVEDO15
C SOLVE (B) (PJ) = BI, DEVELOPING THE INVERSE OF B IN THE PROCESS.
                                                                                           INVED 016
       D0100[=1, M7
                                                                                           INVEDG17
       D0100J=1,H7
                                                                                           INVESC18
  100 BINV (I. J) = 6.0
                                                                                           INVEDC19
                                                                                           INVECCEO
       00110K=1, M7
       BINV (K, K) = 1 . C
                                                                                           INVEDC21
       PJ(K)=AI(K)
                                                                                           INVEDUZZ
                                                                                           INVESC23
  116 IS(K)=3
       DO17 0L=1, M7
                                                                                           INVEGCZL
       U0120K=1,H7
                                                                                           INVEDU25
       IF (IS(K) . NE. G) GOT C120
                                                                                           INVECTOR
       IF (ABS(B(K, L)).GT.EPSI)GOTO130
                                                                                           INVEDE27
   126 CONTINUE
                                                                                           INVEDC28
C CAN DROP OUT OF THIS LOOP ONLY IF A IS ILL-CONDITIONED OR SINGULAR.
                                                                                           INVEGG29
       WRITE(6,1000)
                                                                                           INVECE30
                                                                                           INVECC31
       CALL EXIT
       RE TURN
                                                                                           INVESC32
  130 IS(K)=L
                                                                                           INVECC33
       T=1./3(K,L)
                                                                                           INVEDO34
       PJ(K)=PJ(K)+T
                                                                                           INVESC35
       DU140J=1, M7
                                                                                           INVEGC36
       B(K, J) = B(K, J) *T
                                                                                           INVESC37
  146 BINV (K, J) = BINV (K, J) *T
                                                                                           INVEDC38
       U0160I=1, H7
                                                                                           INVEDG39
       IF (I.EQ.K) GOTO160
                                                                                           INVEDG40
       T=B(I.L)
                                                                                           INVEDD41
       IF (ABS(T).LE.EPSI)GOTO160
                                                                                           INVEDU42
       11=PJ(I) - T*PJ(K)
                                                                                           INVECO43
       IF (ABS(T1).LE.EPS1)T1=0.C
                                                                                           INVEOC44
       PJ(I)=T1
                                                                                           INVEDG45
       00150J=1, H7
                                                                                           INVEDC46
       T1=8(I,J) - T*8(K,J)
                                                                                           INVECC47
       IF (ABS(T1).LE.EPSI)T1=0.0
                                                                                           INVEDG48
        B(I, J)=T1
                                                                                           INVEDC49
       T1=BINV(I,J) - T*EINV(K,J)
                                                                                           INVECCSO
       IF (ABS(T1).LE.EPSI)T1=0.C
                                                                                           INVECU51
  150 BINV (I.J)=T1
                                                                                           INVEDO52
  160 CONTINUE
                                                                                           TNVF0053
  170 CONTINUE
                                                                                           INVED054
C BINV CONTAINS THE INVERSE OF B, UP TO A PERMUTATION OF THE ROMS.
                                                                                           INVEOUS5
       D0180L=1, M7
                                                                                           INVEDUSE
                                                                                           INVESS57
       I=IS(L)
```

- HERNING BOUND B	
OI(I)=PJ(L)	INVE0058
DO188J=1, H7	INVEGES9
180 B(I,J)=EIN/(L,J)	INVEO 06 0
G B NOW CONTAINS THE INVERSE AND BI CONTAINS THE SOLUTION.	INVEDG61
RETURN	INVEDO62
1000 FORMAT(60HOMATRIX TO BE INVERTED IS ILL-CONDITIONED, PERHAPS	SINGUINVED 063
1LAR.)	INVEDO64
1001 FGRHAT(12H *****INVERT)	INVEDO65
END THE PROJECT STATES AND THE STATE	INVEOO66

```
SUBROUTINE OBJ1 (NZ,NP, IR,IA, IS,IBV,TC,BORIG,RHS,C1,ND1,ND2,ND3, OBJ10001
                          ND4, ND51
                                                                                   0BJ10002
C COMPUTE AND STORE THE PHASE 1 OBJECTIVE FUNCTION.
                                                                                   OBJ19003
      COMMON/P1/N, M, ITYPE, NSTRAT, NOORL1, NBVRL1, NTITE1, NCORL2, NB VRL2, NTITE2, MXLIST, LISTOP, IT APE, IFB, MXITER, MBINV, IOUTPT,
                                                                                   OBJ10004
                                                                                   08J10005
                  ITRACE, MSTART, TIME1, TOL1, TOL2, PCBUB, ALPHA (10)
     2
                                                                                   90001180
      COMMON/P2/EPSI, EPSIM, BIGN, BEGTM, M1. M2. M3, M4, N1, MP1, MP2, NM3, NM1M2, OBJ10007
                  NM1H3, N1P2, NP1, NSUM, NTC, H10
                                                                                   08110008
      DIMENSION NZ (ND1), NP(ND1), IR (ND2), IA (ND2), IS (ND4), IBV (ND4)
                                                                                   08110009
      DIMENSION TG (NO3), BORIG (NO4), RHS (NO4), C1 (NO5) IF (ITRACE-GE-1) WRITE (6,1000)
                                                                                   08310010
                                                                                   0BJ10011
      DO100K=1, H
                                                                                   0BJ10012
  106 IS(K)=0
                                                                                   09110013
      D0110K=1,M
                                                                                   09110014
      IF (IBV (K) .LE .NM 1M3) GOTO 11C
                                                                                   08J10615
      KK=IBV(K) -NH3
                                                                                   OBJ15016
      IS (KK)=1
                                                                                   08319617
  110 CUNTINUE
                                                                                   OBJ10018
                                                                                   08J10019
      D0130J=1,N
      NPOINT=NP(J)
                                                                                   08J10020
      NZEROS=NZ (J)
                                                                                   08J10021
                                                                                   08J10622
      Q1=0.0
      D0120K=1, NZ EROS
                                                                                   OBJ10023
      NPOINT=NPOINT+1
                                                                                   0BJ10024
      KK=IR(NPOINT)
                                                                                   OBJ10325
      IF (IS (KK) . EQ . ( ) GO TO 120
                                                                                   08J10026
      INDEX=IAINPCINT)
                                                                                   08J1JC27
      Q1=Q1+TC(INDEX)
                                                                                   0BJ10028
 120 CONTINUE
                                                                                   08113629
  130 C1(J)=-Q1
                                                                                   08J10G3G
      1F (M3.EQ. 0) GOTO 150
                                                                                   08J10031
      KK=H1+H2
                                                                                   ORJ10032
      D0140J=NP1, NM3
                                                                                   OBJ10033
      KK=KK+1
                                                                                   0BJ10634
      C1 (J)=0.0
                                                                                   06J10035
      IF (15 (KK) . EQ . 6) 60 10140
                                                                                   08J10C36
      C1(J)=1.0
                                                                                   OBJ10037
  140 CONTINUE
                                                                                   OBJ10638
  150 BB=0.0
                                                                                   08J10039
      CC=0.0
                                                                                   OBJ10040
      LIHIT=M1+1
                                                                                   08J10C41
      DO160I=LIMIT,M
                                                                                   08J10042
      IF (15(1).EQ. 0)GOTO160
                                                                                   08J10643
      BB=BB-RHS (1)
                                                                                   OBJ10044
      CC=CC-BORIG(1)
                                                                                   08110045
  160 CONTINUE
                                                                                   08310046
      RHS(MP2 = BB
                                                                                   08J10C47
      BORIG(MP2)=CC
                                                                                   OBJ10C48
      RE TURN
                                                                                   08110649
1000 FORHAT(10H *****0EJ1)
                                                                                   OBJ10050
                                                                                   0BJ10051
```

```
SUBROUTINE RSTART (IF, INUSE, IBV, NBV, IUPPER, INS, F, BI, BN, B, FMS,
                                                                                 RSTADOC1
                            NI, NF, NO4, NO5, ND10, NDMS2, NDMS3, IENTRY)
                                                                                 RSTA0002
C PREPARE A RESTART TAPE OR BEGIN A JOB FROM A PREVIOUSLY PREPARED
                                                                                 RSTADGO3
C RESTART TAPE.
                                                                                 RSTA0004
                                                                                 RSTATOO5
      COMMON/P1/N, M, ITYPE, NSTRAT, NOORL 1, NBVRL 1, NTITE1, NOORL 2, NB VRL 2,
     1
                  NTITE2, MXLIST, LISTOP, ITAPE, IFB, PX ITER, MBINV, IOU TPT,
                                                                                 RSTADCO6
                  ITRACE, MSTART, TIME1, TOL1, TOL2, PCBLB, ALPHA (10)
                                                                                 RSTACCO7
      COMMON/PZ/EPSI, EPSIM, BIĞN, BEĞTH, MI, MZ, M3, M4, NI, MP1, MP2, NM3, NM1M2, RSTADDO8
                  NM1M3,N1P2,NP1,NSUM,NTC,M10
                                                                                 RSTADDOG
      COMMON/P3/NO CNOT, UNOT, IBUBOP, LPFA SE, NODRUL, NBVRUL, NTIGHT, NLIST,
                                                                                 RSTADC 10
                  NLISTS, NFEAS, LSTMX, ITRT CT, ITRMAX, BLB, NBRNOD, PBRNOD,
                                                                                 RSTAUG11
                  NBRVAR, NUPDWN, XBRNOD, TBRNOD, NODE, LNODE, Z, BOUNDL, BCUNDU, RSTADU12
                                                                                 RSTADC13
                  TSIG, IFEAS, IBRVR1, IUPON1, XBRVR1, IBRVR2, IUPON2, XBRVR2,
                  L10, NITER, NOINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IECJ
                                                                                 RSTADC14
      COMMON/P4/SAVE, KBRAN, X1
                                                                                 RSTADG15
      DIMENSION IF (NI), INUSE (ND10), 18V (104), NBV (NO5), IUFPER (ND5),
                                                                                 RSTADU16
                  IMS(NOMS2)
                                                                                 RSTAGE 17
      DIMENSION F (NF), &I(ND4), BN(ND5), 6 (NC4, NC4), FMS(ADMS3)
                                                                                 RSTAGG 18
      IF (ITRACE.GE.1) WRITE(6,1002)
                                                                                 RSTADG19
       IF (IENTRY.EQ. 1) GOT 0130
                                                                                 RSTA0020
                                                                                 RSTAD021
C BEGIN A JOB FROM A RESTART TAPE.
      WRITE (6, 1000)
                                                                                 RSTADC 22
      REWIND 4
                                                                                 RSTACC23
      REWIND 7
                                                                                 RSTAGG24
      REWINO 8
                                                                                 RSTANG25
      READ(7)
                  MIC.
                                                                                 RSTADE 26
                  NODNOT, UNOT, IBUBOP, LPHA SE, NODRUL, NBVRUL, NTIGHT, NLIST,
                                                                                 RSTADG27
                  NLISTS, NFEAS, LSTMX, ITRTCT, ITRMAX, BLB, NBRNOD, PBRNOD,
                                                                                 RSTAGE28
     3
                  NBRVAR, NUPDWN, XBRNOD, TBRNOD, NODE, LNODE, Z, BOUNDL, BCUNDU, RSTAGE 29
                  TSIG, IFEAS, IBRVR1, IUPDN1, XBRVR1, IBRVR2, IUPDN2, XBRVR2,
                                                                                 RSTADD30
                  L10, NITER, NOINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IECJ,
                                                                                 RSTACC31
                  SAVE, KBRAN, X1
                                                                                 RSTAGC 32
      IF (NLIST. EQ. 0) GCT 0110
                                                                                 RSTADC33
      00100J=1, NLIST
                                                                                 RSTADO34
      READ(8)
                 10, (IMS (I), I=1, NDMS2), (FMS(I), I=1, NDMS3)
                                                                                 RSTA0035
      CALL WRITHS (2, IMS, NDMS2, 10)
                                                                                 RSTADE 36
                                                                                 RSTADO37
      CALL WRITHS (3,FMS, NDMS3, IO)
  100 CONTINUE
                                                                                 RSTAGE 38
  110 IF (2* (NODE/ 2) . NE. NODE ) GOT 0120
                                                                                 RSTACC39
      RE AD (8)
                  (IBV(I), I=1, NO4), (NBV(I), I=1, NO5), (IUPPER(I), I=1, NO5),
                                                                                 RSTAGG40
                  (BI(I), I=1,ND4), (3N(I), =1,ND5), LL1, LL2, LL3,
                                                                                 RSTADE 41
                  ((B(I,J),I=1,N04),J=1,N04)
                                                                                 RSTAD042
      WRITE(4)
                  (IBV(I), i=1, ND4), (NEV(I), I=1, ND5), (IUPPER(I), I=1, ND5),
                                                                                 RSTADE 43
                  (BI(I), I=1, NO4), (BN (I), I=1, NO5), LL1, LL2, LL3,
                                                                                 RSTADE 44
                  ((B(I,J),I=1,NO4),J=1,N(4)
                                                                                 RSTADC45
                  (IF(I), I=1, NI), (F(I), I=1, NF)
  120 READ(7)
                                                                                 RSTANC 46
      REWIND 4
                                                                                 RSTAGL47
      REWIND 7
                                                                                 RSTADC 48
      REWIND &
                                                                                 RSTADE 49
      RETURN
                                                                                 RSTATE50
C PREPARE A RESTART TAPE.
                                                                                 RSTADD51
  130 WRITE (6,1001)
                                                                                 RSTA0052
      REWIND 4
                                                                                 RSTADC 53
      REWIND 9
                                                                                 RSTA0054
      REWIND 10
                                                                                 RSTAGG55
      WRITE(9)
                                                                                 RSTA0056
                  NODNOT, UNOT, IBUBOP, LPHASE, NODRUL, NBVRUL, NTIGHT, NLIST,
                                                                                 RSTADG57
```

```
NL ISTS, NF EAS, LSTMX, ITRT CT, ITRMAX, BLB, NBRNOD, PBR NOC.
                                                                                     RSTA0058
                  NBRVAR, NUPDWN, XBR NOD, TBENOD, NODE, LNODE, Z, BOUNDL, BCUNDU, RSTACC59
    4
                  TSIG, IFEAS, IBRVR1, IUPDN1, XBRVR1, IBRVR2, IUPDN2, XBRVR2,
                                                                                     RSTACC60
    5
                  LIC, NITER, NOINV, MT, IPHASE, NPHASE, NH3M7, IALGO, IEOJ,
                                                                                     RSTACC61
                 SAVE, KBRAN, X1
                                                                                     RSTA0C62
                 (IF(I), I=1, NI), (F(I), I=1, NF)
     WRITE(9)
                                                                                     RSTACC63
      IF (NLIST. EQ. C) GOT (150
                                                                                     RSTADC64
      6014015=1,MXLIST
                                                                                     RSTAGE 65
                                                                                     RSTADE 66
      IF (INUSE(ID) . EQ. 0 1GOT 01 40
     CALL READMS (2.1MS, NDMS2, 10)
CALL READMS (3, FMS, NDMS3, 10)
                                                                                     RSTADE 67
                                                                                     RSTACC68
      WRITE(1) 10, (IMS (I), I=1, NOMS2), (FMS(I), I=1, NOMS3)
                                                                                     RSTACC69
 140 CONTINUE
                                                                                     RSTACC78
 150 IF (2*(NODE/2).NE. NODE) GCT C160
                                                                                     RSTADG71
                  (IBV(I), I=1, ND4), (NBV(I), I=1, ND5), (IUPPER(I), I=1, ND5),
      READ(4)
                                                                                     RSTADC72
                  (B1(1), 1=1, NO4), (BN(I), I=1, ND5), LL1, LL2, LL3,
                                                                                     RSTADE73
      \begin{array}{ll} ((8(I,J),I=1,NO4),J=1,NC4) \\ \text{MRITE}(10) & (18V(I),I=1,ND4), (N8V(I),I=1,ND5), (IUPPER(I),I=1,ND5), \end{array} 
                                                                                     RSTACC74
                                                                                     RSTACC75
                  (81(1), I=1, ND4), (3N(I), I=1, ND5), LL1, LL2, LL3,
                                                                                     RSTADO76
                  ((B(I,J),I=1,N04),J=1,NC4)
                                                                                     RSTAGE 77
 16C END FILE 9
                                                                                     RSTACC78
     END FILE 10
                                                                                     RSTADE79
                                                                                     RSTADEBS
      RE TURN
                                                                                     RSTACC81
1000 FORMAT(38+68EGINNING THE JOB FROM RESTART TAPES.)
                                                                                     RSTADE 82
1001 FORMAT(24HJRESTART TAPES PREPARED.)
                                                                                     RSTAUC 83
1602 FORMAT(12H *****RSTART)
                                                                                     RSTAGE84
     END
                                                                                     RSTACC85
```

```
SUBROUTINE SIMPLE (NZ,NP, IR, IA, IS,NV, IBV, NBV, IUPPER, TG, RHS, GZ,C1, SIMPOGG1
                          BI.BN. U.PJ.BINV. XJ.V.XZ.B.ND1.ND2.ND3.ND4.ND5, SIMPOCO2
                          ND6, ND7)
                                                                           SIMP0003
C PRIMAL AND DUAL SIMPLEX ALGCRITHMS FOR SOLVING THE LP.
                                                                           SIMPODO4
      COMMON/P1/N, M, ITY FE, NSTRAT, NODRL1, NBVRL1, NTITE1, NODRL2, NBVRL2,
                                                                           SIMPOCO5
                NTITE2, MXLIST, LISTOP, IT APE, IFB, MXITER, MBINV, IOUTPT,
                                                                           SIMPOCO6
                 ITRACE, PSTART, TIME1, TOL1, TOL2, PCBUB, ALPHA(1C)
                                                                           SIMPOOO7
      COMMON/P2/EPSI, EPSIM, DIGN, BEGTM, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2, SIMPO CO8
                NM1H3, N1P2, NP1, NSUM, NTC, M10
                                                                           SIMPOOU9
      COMMON/P3/NOONOT, UNOT, I BUBOP, L PHASE, NODRUL, NB VRUL, NTIGHT, NLIST,
                                                                           SIMPOC10
                 NLISTS, NFEAS, LSTMX, ITRT (T, ITRMAX, BLO, NBRNOD, PBRNOD,
                                                                           SIMPO011
                NBRVAR, NUFOWN, XBR NOO, TBRNOO, NODE, LNODE, Z, BOUNDL, BCUNDU, SIMPOO12
                 TSIG, IFEAS, IBRVF1, IUPON1, XBRVR1, IBRVR2, IUPON2, XBRVR2,
                                                                           SIMPOC13
                L10, NITER, NBINV, M7, IPHASE, NPHASE, NH3M7, IALGO, IECJ
                                                                           SIMPOC14
                                                                           SIMPO015
      DIMENSION IS (NO4), NV (NO6), I dV (ND4), NBV (ND5), ILPPER (ND5)
      , (AD6), XZ (ND6), U (ND6), PJ (ND4), XJ (ND4), V (ND6), XZ (ND6),
                                                                           SIMPOC16
                B (NO4 , NC4)
                                                                           SIMPOC17
      IF (ITRACE.GE.1) HRITE(6,1022)
                                                                           SIMF0018
      1F (IOUTPT.LE.1) GO 10110
                                                                           SIMP0019
      IF (IALGO.EQ.2)GCTC100
                                                                           SIMP0020
      WRITE (6,1000)
                                                                           SIMPO021
      IF (NODE . NE . 1)GOTO110
                                                                           SIMP0022
      IF (IPHASE .EQ.1) WRITE(6,1001)
                                                                           SIMP0023
      IF (IPHASE.EQ. 2) WRITE(6, 1002) NPHASE
                                                                           SIMPO024
      GOTO110
                                                                           SIMPOC25
 100 WRITE(6,1003)
                                                                           SIMP0026
 116 ITER=0
                                                                           SIMP0027
           **SIMP0028
G INCREMENT THE ITERATION COUNTER. REINVERT THE BASIS MATRIX IF
                                                                           SIMPOG29
C NECESSARY.
                                                                           SIMPOD30
               120 ITER=ITER+1
                                                                           SIMPD032
      NITER=NITER+1
                                                                           SIMPOG33
      NBINV=NBINV+1
                                                                           SIMPCC34
      IF (ITER. GT. MXITER IGOTO630
                                                                           SIMP0035
      IF ( NBINV. NE. MEINV )GOTO160
                                                                           SIMPOC36
C REINVERT THE BASIS MATRIX EVERY MBINV ITERATIONS.
                                                                           SIMP0037
      NBINV=0
                                                                           SIMPOC38
      IF (IOUTPT .GE . 2) HR ITE (6, 10C4) NITER
                                                                           SIMP0039
      IF (IOUTPT.LE. 4) GOTO140
                                                                           STMPODAO
      WRITE (6,1005)
                                                                           SIMPOG41
      DO130I=1, M7
                                                                           SIMP0042
  130 WRITE(6,1006) IBV(I),(8(I,J),J=1,M7),BI(I)
                                                                           SIMP0043
 140 CALL BINVRT (NZ,NF, IR, IA, IS, IBV, NEV, IUPPER, TC, RHS, C2, C1, BI, U, PJ,
                                                                           SIMPO044
                   BINV ,B, ND1 , N C2 , ND3 , N (4 , NO5 , ND6 , ND7 )
                                                                           SIMPOC45
      IF (IOUTPT.LE.4) GOTO160
                                                                           SI HPO 046
      WRITE(6,1005)
                                                                           SIMPOC47
      D01501=1, M7
                                                                           SIMPOC48
  150 HRITE(6,1006) IBV(I),(B(I,J),J=1,M7),BI(I)
                                                                           SIMPUG49
  160 GOTO (173, 300), IAL GO
                                                                  ********SIMPOC51
                        **************************
C PRIMAL ALGORITHM.
                                                                           SIMP0052
C PRICE-OUT THE NON-BASIC VARIABLES. THE ENTERING VARIABLE IS THE FIRST SIMPUCES
C ONE ENCOUNTERED HAVING NEGATIVE REDUCTO COST.
                                                              ************SIKP0055
 170 00200IPOS=1,L10
                                                                           SIMPOC56
      KIND=NBV(IPOS)
                                                                           SIMPOG57
```

```
DO1801=1, M7
                                                                                                                                                   SIMPOSSA
                                                                                                                                                   SIMP8059
   180 PJ(I)=0.0
            CALL GETCOL (NZ, NP, IR, IA, IS, TC, RMS, CZ, C1, PJ, NO1, NO2, NO3, NO4, NO5,
                                                                                                                                                  SIMPO060
                                                                                                                                                   SIMPOG61
          1
                                       KIND , NZEROSI
            Q1=0 .
                                                                                                                                                   SIMPOC62
                                                                                                                                                   SIMP3063
            D0190J1=1,NZEROS
                                                                                                                                                   SIMPOD64
            J=IS(J1)
    190 Q1=Q1 + B(M10,J)*PJ(J)
                                                                                                                                                   SIMPOD65
                                                                                                                                                   SIMPOO66
            Q1=Q1 + B(M1C, MP1)*PJ(MP1)
            IF (IPHASE.EQ.2)Q1=Q1 + 8(M10, MP2)+PJ(MP2)
                                                                                                                                                   SIMPOD67
C Q1 IS THE REDUCED COST FOR VARIABLE J=KIND.
IF(IUPPER(IPOS).EG.1)Q1=-Q1
                                                                                                                                                   SIMPOD68
                                                                                                                                                   SIMPOD69
                                                                                                                                                   SIMP0070
            IF (Q1.LT.EPSIM+100C.)GOTO240
    200 CONTINUE
                                                                                                                                                   SIMPOO71
C FOR ALL NON-BASIC VARIABLES, THE REDUCED COST IS NON-NEGATIVE.
                                                                                                                                                   SIMP0072
                                                                                                                                                   SIMP0073
            IF (IPHASE.NE.2) GO TO 640
                                                                                                                                                   SIMPO074
            IF (NPHASE .EQ. 2) GO 10640
C CHECK IF ANY ARTIFICIALS REMAIN IN THE BASIS.
                                                                                                                                                   SIMP0075
            INDEX=0
                                                                                                                                                   SIMPOO76
            DO210 I=1, M7
                                                                                                                                                   SIMP0077
                                                                                                                                                   SIMPOG78
            J=IdV(I)
                                                                                                                                                   SIMPOC79
            IF (J.GT.NM1M3 .AND. J.LE.N1) INDEX=1
    210 CONTINUE
                                                                                                                                                   SIMP0080
                                                                                                                                                   SIMPOG81
            IF (BI (MP2). GE.EPSIN+1000. JGOTO220
            IF (INDEX.EQ.1)GCT0586
                                                                                                                                                   SIMP0082
C PHASE 1 TERMINATES. ENTER PHASE 2.
                                                                                                                                                   SIMPO083
                                                                                                                                                   SIMPOO84
    220 IF (LOUTPT.GE.2) HRITE(6,1007)NITER
                                                                                                                                                   SIMP0085
            M10=M10-1
            IF (INCEX.EQ. 1) GOT C230
                                                                                                                                                   SIMP0086
C THERE ARE NO ARTIFICIALS IN THE BASIS. DELETE THE PHASE 1 OBJECTIVE
                                                                                                                                                   STMPAGET
C FUNCTION FROM THE PROGRAM.
                                                                                                                                                   SIMPODAS
                                                                                                                                                   SIMPOD89
            M7=MP1
                                                                                                                                                   SIMPOG90
            IPHASE=1
                                                                                                                                                   SIMP0091
            NPHA SE = 0
            NH3M7=N+H3+H7
                                                                                                                                                   SIMP0092
            GOTO 120
                                                                                                                                                   SIMPO093
C THERE ARE ARTIFICIALS IN THE BASIS. MAINTAIN THE PHASE 1 OBJECTIVE
                                                                                                                                                  SIMF0094
                                                                                                                                                  SIMP0095
C FUNCTION AS A CONSTRAINT.
   230 NPHASE=2
                                                                                                                                                   SIMPOC96
            GOT0120
                                                                                                                                                   SIMP0097
Construction of the constr
                                                                                                                                                  SIMPOG99
C PRIMAL ALGORITHM.
C SELECT THE LEAVING EASIC VARIABLE.
                                                                                                                                                  SIMPO 100
              C COMPUTE THE UPDATED COLUMN, XJ = B-INVERSE * PJ. 240 DO260I=1,M7
                                                                                                                                                  SIMP0102
                                                                                                                                                  SIMP0103
                                                                                                                                                  SIMP0104
            Q1=0.0
            D0250J1=1,NZEROS
                                                                                                                                                  SIMPO105
            J=IS (J1)
                                                                                                                                                  SIMP0106
    250 Q1=Q1 + B(I, J)*FJ(J)
                                                                                                                                                   SIMP0107
            Q1=Q1 + 8(I, MP1)*PJ(MP1)
                                                                                                                                                  SIMP0108
            IF (IPHASE.EQ.2) Q1 =Q1 + 8(I, HP2) *PJ(HP2)
                                                                                                                                                  SIMPOIDS
   260 XJ(I)=Q1
                                                                                                                                                  SIMPU110
C COMPUTE THE MINIMUM OVER XJ(I).GT.O OF THE BASIC VARIABLE VALUES
                                                                                                                                                  SIMP0111
C DIVIDED BY XJ(I).
                                                                                                                                                  SIMP0112
                                                                                                                                                  SIMP0113
            XPIV=BIGN
            DO280I=1, M7
                                                                                                                                                  SIMPOLLA
```

```
IF(I.EQ.MP1)GOTO260
                                                                 SIMPU115
      Q1=XJ(I)
                                                                     SIMPU116
      IF (IUPPER (IPOS) . EQ. 1) Q1 = -Q1
                                                                     SIMP0117
C Q1 IS XJ(I).
                                                                     SIMP0118
     IF (Q1.LT.EPSI) GOTO270
                                                                     SIMP0119
      Q2=8I(I)
                                                                     SIMP0120
C Q2 IS THE BASIC VARIABLE VALUE.
                                                                     SIMP0121
      IF(QZ/Q1.GE.XPIV)GUT0283
                                                                     SIMP0122
      KPIV=I
                                                                     SIMP0123
C KPIV INDICATES THE LEAVING VARIABLE.
                                                                     SIMPC124
      XPIV=Q2/Q1
                                                                     SIMP0125
      ITHIA=1
                                                                     SIMP0126
                                                                     SIMP0127
C ENTERING VARIABLE DOES NOT FORCE ANY VARIABLE TO ITS UPPER BOUND
C (ITHIA = 1).
                                                                     SIMP0128
                                                                     SIMP0129
      GOT0283
  270 Q1=-Q1
                                                                     SIMP0130
      IF(Q1.LT.EPSI) GOTO280
                                                                     SIMP0131
      I1= IBV(I)
                                                                     SIMP 1132
      Q2=U(I1)-BI(I)
                                                                     SIMP0133
      IF (Q2/Q1.GE.XPIV)GOTO283
                                                                     SIMP0134
      KPIV=I
                                                                     SIMP0135
      XPIV=Q2/Q1
                                                                     SIMPS136
      ITHIA= 2
                                                                     SIMP0137
G ENTERING VARIABLE FORCES LEAVING VARIABLE TO ITS UPPER BOUND
                                                                     SIMP0138
C (ITHIA = 2).
                                                                     SIMP0139
  280 CONTINUE
                                                                     SIMPU14
      IF (U(KIND) . GE . XPIV) GOTO 290
                                                                     SIMP0141
      ITHIA=3
C ENTERING VARIABLE ENTERS AT ITS UPPER BOUND (ITHIA = 3).
                                                                     SIMP0143
     XPIV=U(KIND)
                                                                     SIMPG144
  290 IF (XPIV.GE. BIGN) GOTO615
                                                                  SIMP0145
      IBVK=IBV(KPIV)
     GOTO448
                                                                     SIMPU147
C DUAL SIMPLEX ALGORITHM.
                                                          SIMP0149
300 IF (IBUBOP. EQ. 1) GOTO310
                                                     SIMP 152
C TEST THE OBJECTIVE VALUE AGAINST THE BEST UPPER BOUND.

IF(-BI (MP1)+TSIG.GE.(1.-TOL1)*UNOT)GOTO623

C COMPUTE THE MINIMUM OF THE RIGHT-MAND-SIDES.
                                                              SIMP@153
                                                                     SIMP0154
                                                                     SIMP0155
  310 BMIN=BIGN
                                                                     SIMPG156
     KPIV=3
                                                                     SIMP0157
      D0320I=1, M7
                                                                     SIMP0158
      IF(I.EQ.MP1)GOTO32.
                                                                     SIMP0159
      IF (BI(I).GE.BHIN) GOTO 320
                                                                     SIMPJ16J
      BMIN=BI(I)
                                                                     SIMP0161
     KPIV=I
                                                                     SIMPU162
  320 CONTINUE
                                                                     SIMP0163
      JPIV=0
                                                                     SIMP0164
      D0330I=1,M7
                                                                     SIMPG165
      IF (I.EQ.MP1)GOTO330
                                                                     SIMP.166
      I1= I8V(I)
                                                                     SIMPJ167
      IF (U(I1)-81(I) .GE.BMIN) GOTO330
                                                                     SIMP0166
      BMIN=U(I1)-BI(I)
                                                                     SIMPG169
     JPIV=I
                                                                     SIMPU17:
  330 CONTINUE
                                                                     SIMP 0171
```

```
SIMP0172
C IF THIS MINIMUM IS NONNEGATIVE, WE ARE AT THE OPTIMUM.
                                                                         SIMP0173
      IF (BMIN.GE. EPSIM*1000.) G070640
                                                                         SIMPO174
      TTHIA=1
                                                                         SIMP0175
      IF (JP IV.EC. 0)GOTO340
      ITHIA=2
                                                                         SIMP0176
      KPIV=JPIV
                                                                         SIMP0177
 340 IBVK=IBV(KPIV)
                                                                         SIMP0178
C DUAL SIMPLEX ALGORITHE.
                                                                         SIMPO 180
C SELECT THE ENTERING VARIABLE. SIMPO181
C COMPUTE THE MINIMUM OVER XJ(I).LT.O OF THE DUAL VARIABLE VALUES
                                                                         STHP0183
C DIVIDED BY -XJ(I).
                                                                         SIMPO184
      XPIV=dIGN
                                                                         SIMP0185
                                                                         SIMPO186
      KIND=0
      D0400JP0S=1,L10
                                                                         SIMPO187
      (209L) VEN=ONIL
                                                                         SIMP0188
      D0350I=1.M7
                                                                         SIMP0189
                                                                         SIMP0190
 350 PJ(I)=0.0
      CALL GETCOL (NZ, NP, IR, IA, IS, TC, RHS, CZ, C1, PJ, NO1, NCZ, ND3, ND4, ND5,
                                                                         SIMP0191
                   JINO ,NZEROS)
                                                                         SINP0192
    1
                                                                         SIMP0193
      Q1=0.0
      D0360J1=1,NZEROS
                                                                         SIMP0194
                                                                         SINPO195
      J=IS(J1)
 360 Q1=Q1 + B(KPIV, J) *PJ(J)
                                                                         SIMP0196
      Q1=Q1 + B(KPIV, MP1) *PJ(MP1)
                                                                         SIMP0197
      IF (IPHASE.EQ.2)Q1=Q1 + B(KPIV, MP2)+PJ(MP2)
                                                                         STHP0198
                                                                         SIMP0199
      IF (ITHIA.EQ.2)GOTO370
      IF (IUPPER (JPOS) .EQ. 6) Q1 =-Q1
                                                                         SIMPO 200
      GOTO380
                                                                         SIMP0 201
  370 IF (IUPPER(JPOS) .EQ. 1) Q1=-Q1
                                                                         SIMP0202
  380 IF (Q1.LE.EPSI)GOTO400
                                                                         SIMP0203
C Q1 IS -XJ(I).
                                                                         SIMP0204
      02=0.0
                                                                         SIMPO205
                                                                         SIMPO206
      D0390J1=1,NZEROS
      J= IS (J1)
                                                                         SIMP0207
  390 42=Q2 + B(MP1,J)*PJ(J)
                                                                         SIMP0208
      Q2=Q2 + B(MP1,MP1)*PJ(MP1)
                                                                         SIMP0209
      IF (IPHASE.EQ.2) Q2 =Q2 + B(MP1, MP2) *PJ(MP2) IF (IUPPER(JPOS).EQ.1) Q2=-G2
                                                                         SIMPO 210
                                                                         SI MP0 211
C QZ IS THE DUAL VARIABLE VALUE.
                                                                         SIMP0212
      IF (Q2/Q1.GE.XPIV)GOTO400
                                                                         SIMP0213
      XPIV=02/01
                                                                         SIMPO214
      KIND=JIND
                                                                         SIMPO215
                                                                         SIMPO 216
      IPOS=JPOS
 400 CONTINUE
                                                                         SIMPS217
C IF THERE IS NO PIVOT ELEMENT, THE PRIMAL PROGRAM IS INFEASIBLE
                                                                         SIMPO218
C (THE DUAL PROGRAM IS UNBOUNDEC) .
                                                                         SIMP0219
      IF (KIND.EQ. 0) GOTO 580
                                                                         SIMPO 220
C COMPUTE THE UPDATED CCLUMN, XJ = 8-INVERSE * PJ.
                                                                         SINP0 221
                                                                         SIMPOZZZ
      D04161=1, P7
                                                                         SIMP0223
  410 PJ(I)=0.0
      CALL GETCOL (NZ, NP, IR, IA, IS, TC, RHS, C2, C1, PJ, NO1, ND2, ND3, ND4, ND5,
                                                                         SIMP0224
                  KIND, NZEROS)
                                                                         SIMP0225
      D0430I=1, M7
                                                                         SIMP0226
                                                                         SIMP0227
      Q1=0.0
      D0420J1=1,NZEROS
                                                                         SIMP0228
```

	J=IS(J1)	
42	0 Q1=Q1 + B(I, J)*PJ(J)	
	Q1=Q1 + B(I, HP1)*PJ(HP1)	SIMP0231
	IF (IPHASE.EQ.2)Q1=Q1 + B(I, MP2)*PJ(MP2)	SIMP0232
	0 XJ(I)=Q1	SIMPO233
	• • • • • • • • • • • • • • • • • • • •	
	IMAL AND DUAL SIMFLEX ALGORITHMS.	SIMP0235
CPI	VOT THE ENTERING AND LEAVING VARIABLES.	SIMP0236
44	O IF (IOUTPT.EQ.5) WRITE (6,1008) NITER, KIND, IBVK, ITHIA	SIMP0238
	INDEX=0	SIMP0239
	IF (IUPPER (I FOS) .EG. 1) GOTO480	
	GOTO (510,470,450), ITHIA	SIMP0241
45	IUPPER(IPCS)=1	SI MP0 242
	an (IPOS) = L(KIND)	SIMP0243
	D0460I=1, M7	SIMP0244
46	0 BI(I)=BI(I) - U(KING)*XJ(I)	SIMP0245
	6070120	SIMP024E
47	BI(KPIV)=BI(KPIV) - U(IBVK)	SIMP0247
	1011 28111 65 7-1	SIMPJ248
	BN(IPOS)=U(IBVK)	SIMP3249
	G0T051C	SI MPO 250
40	IUPPER(IPCS)=0	SIMP0 251
	BN(IPOS)=0.0	SIMPO252
C CH	ANGE THE RIGHT-HAND-SIDE AFTER THE FIVOT.	SIMPO253 SIMPO254
		SIMP0255
40	GOTO(510,470,490),ITHIA	SIMPOZSE
	0 BI(I)=BI(I) + U(KINO)*XJ(I)	SIMP0257
50	GOTO126	SI NP0258
51	5 T=1./XJ(KPIV)	SIMP0259
	BI(KPIV)=EI(KPIV)*T	SI MP0 260
	00520K=1.H7	SIMP0261
52	B (KPIV, K) = B (KPIV, k) *T	SIMP3262
STALKS I	D0540J=1,H7	SIMP0263
	IF (J.EQ.KPIV)GOTO540	SIMP0264
	T=XJ(J)	SIMPO265
	IF (ABS(T) .LE.EPSI) GOTO540	SIMP026E
	T1=8I(J) - T*8I(K+IV)	SIMP0267
	IF (ABS(T1).LE.EPSI)T1=0.0	SINP0268
	BI(J)=T1	SIMP0269
	D0530K=1,M7	SIMP0 270
	T1=8(J,K) - T*8(KPIV,K)	SIMP1271
	IF (ABS(T1).LE.EPSI)T1=0.0	SIMPG272
53	0 8(J,K)=[1	SIMP0273
54	CONTINUE	SIMP0274
	IF (INDEX.EQ. C) GOTO550	SIMPU275
	BI(KPIV)=BI(KPIV) + U(KIND)	SIMP0276
	DATE THE NBV AND IBV ARRAYS.	SIMP0277
55	I = I d v (KPI v)	SIMP0278
	IBV(KPIV)=NBV(IPOS)	SIMP0279
	IF (I.GT.NM1M3 .AND. I.LE.N1)GOTOSGC	SIMFO 28C
	IF (IALGO.EQ. 2 .AND. I.EQ. N1P2) GOT 0560	SIMP0281
	NBV(IPOS) =I	SI MP0 282
	G0T0120	SI MPD 283
56	0 MBV(1POS)=NBV(L10)	SI MPO 284
	IUPPER(IPCS) = IUPPER (L10)	SIMPOZOS

```
SIMP0286
      BN(IPOS)=BN(L10)
      L10=L10-1
                                                                              SIMPO287
                                                                              SIMPO288
      IF INPHASE . EQ. 1) GOTO120
                                                                              SIMP0289
      D0570I=1, M7
      (I)VEI=L
                                                                              SIMPO 29G
                                                                              SIMF0 291
      IF (J.GT.NH1H3 .AND. J.LE.N1)GOTO120
  570 CONTINUE
                                                                              SIMP0292
C THERE ARE NO ARTIFICIALS IN THE BASIS. DELETE THE PHASE 1 OBJECTIVE
                                                                              SIMP1293
C FUNCTION FROM THE PROGRAM.
                                                                              SIMPO294
      H7=HP1
                                                                              SIMP0295
                                                                              SIMP0296
      IPHASE=1
                                                                              SIMP0297
      NPHASE= 0
                                                                              SIMP0298
      NM3H7=N+M3+M7
      GOTO120
                                                                              SIMP0299
                                                                             SIMPO 300
C FINAL OUTPUT.
                                                                              SIMF0301
C*********************************
                                                                           ***SIMP0 302
  580 IF (IOUTPT.EQ.0) GO TO 600
                                                                              SIMP0303
      WRITE(6,1009)
                                                                              SIMP0334
      1F (10UTPT.LE.2) GO 10600
                                                                              SIMP0305
      IF (IALGO.EQ. 1)GCT0590
WRITE(6,1010)IBVK, BMIN
                                                                              SIMP0306
                                                                              SIMP0307
  590 WRITE(6,1011)(IBV(I), I=1, M7)
                                                                              SIMPO308
                                                                              SIMP0309
      WRITE(6,1012)(BI(I),I=1,M7)
  600 IEOJ=1
                                                                              SIMP0 310
      GOT0640
                                                                              SIMP0311
                                                                              SIMP0 312
  610 WRITE(6,1013)
      WRITE(6,1014)KIND
                                                                              SIMPC313
      WRITE(6,1011)(IBV(I), I=1, M7)
                                                                              SIMP0314
      WRITE(6,1015)(XJ(1),I=1,H7)
                                                                              SIMP0315
                                                                              SIMPO316
      WRITE(6,1012)(BI(I),I=1,M7)
      IEOJ=2
                                                                              SIMP0 317
                                                                              SI HP0 318
      GOT0640
  620 IF (LOUTPT .NE.C) WRITE(6, 1016)
                                                                              SIMP0319
                                                                              SIMP0 320
      IEOJ=3
                                                                              SI MP0 321
      GOT0640
                                                                              SIMPO 322
  630 WRITE(6,1017)
                                                                              SIMP0323
      IEOJ=4
                                                                              SIMP0324
  640 0065 0I=1, N1P2
                                                                              SIHP0325
  650 XZ(I)=0.0
      D0660I=1,NM3M7
                                                                              SIMP0 326
      NV(I)=0
                                                                              SIMP0327
  660 V(I) =0.0
                                                                              SIMP0328
                                                                              SIMP0329
      D0680K=1, H7
      I=IBV(K)
                                                                              SIMP0 330
      NV(I)=I
                                                                              SIMP0 331
      IF (K.EQ.MP1) GOTO670
                                                                              SIMPO 332
                                                                              SIMP0333
      (X) IB=(I)V
                                                                              SIMP0334
      XZ(1)=B1(K)
      G0T0680
                                                                              SIMP0335
                                                                              SIMP0336
  670 V(I) =-8I(K)
                                                                              SIMP0337
      XZ(I)=-3I(K)
  680 CONTINUE
                                                                              SIMP0338
                                                                              SIMP0339
      Z=-BI (MP1)
      IF (IOUTPT.LE.3) GOTO710
                                                                              SI MP0 340
      D0700K=1.H7
                                                                             SIMP0341
      D06901=K, NH3H7
                                                                             SIMP0 342
```

```
IF (NV(I).EQ. 0)G0T0690
                                                                               SIMP0343
     IF (I.EQ.K)GOTO700
                                                                               SIMP0344
                                                                               SIMPO345
     NY (K) =NY (I)
     V(K)=V(I)
                                                                               SIMP0346
                                                                               SIMP0347
     NV(I)=0
                                                                               SIMP0348
     GOTO700
                                                                               SIMP0349
 690 CONTINUE
 700 CONTINUE
                                                                               SI MPO 350
     WRITE(6,1018)
      WRITE(6,1019) (NV( N), V(K), K=1,H7)
                                                                               SI NP0 352
                                                                               SIMP0353
 710 CONTINUE
     D0720I=1,NM3M7
                                                                               SIMP0354
     NV(1)=0
                                                                               SIMPO355
 720 V(I)=0.0
                                                                               SI MP0356
                                                                               SIMP0357
     KK=0
                                                                               SIMP0358
     D0730K=1,L10
     IF (IUPPER (K) .EQ. 0) GOT 0730
     KK=KK+1
                                                                               STMP0 360
     I=N8V(K)
                                                                               SIMP0361
     NV(I)=I
                                                                               SI MPO 362
     V(I)=BN(K)
                                                                               SIMP0363
                                                                               SIMPO 364
     XZ(I)=BN(K)
 730 CONTINUE
                                                                               SIMP0365
     IF (IOUTPT.LE.3)GOTO780
                                                                               SIMP0366
     IF ( KK.EQ. 0) GOTO 76 (
                                                                               SIMP0367
     D0750K=1,KK
                                                                               SIMP0368
                                                                               SIMP0369
     D0740I=K, NM3M7
     IF (NV(I).EQ. 0) GOTO740
                                                                               SI MPO 370
     IF (I.EQ.K) GOTO750
                                                                               SIMP0371
     NY(K)=NY(I)
                                                                               SIMPO 372
     V(K)=V(I)
                                                                               SIMP0373
     NV(I)=0
                                                                               SIMP0374
     6010753
                                                                               SIMP0375
                                                                               SIMP0376
 746 CONTINUE
                                                                               SIMP0377
 750 CONTINUE
      WRITE (6,1020)
                                                                               SIMP0378
     WRITE (6, 1019) (NV(K), V(K), K=1,KK)
                                                                               SIMP0379
 760 IF (IOUTPT.LE.4) GOTO 780
                                                                               SI MP0 380
      WRITE(6,1005)
                                                                               SIMPO 381
     D0770I=1, M7
                                                                               SIMPO 382
 770 WRITE(6,1006)[8V(I),(3(I,J),J=1,M7),8I(I)
                                                                               SIMP0383
                                                                               SIMP0384
 780 IF (IOUTPT.GE.2) WRITE(6, 1021) ITER, NITER
                                                                               SIMP0385
      ITRIOT=ITRIOT + ITER
     IF (NITER.GT. ITRMAX) ITRMAX=NITER
                                                                               SIMP0386
     RETURN
                                                                               SIMP0387
1000 FORMAT (17HGPRIMAL ALGORITHM)
                                                                               SIMP0388
1661 FORHAT(17H ONE PHASE METHOD)
                                                                               SIMPO 389
1002 FORMAT (47H THO PH & SE METHOD - BEGIN COMPUTATIONS IN PHASE, 12) 1003 FORMAT (23HOOUAL SIMPLEX ALGORITHM)
                                                                               SI MPO 390
                                                                               SI MP0 391
1604 FORMAT(32HOBASIS REINVERTED ON ITERATION =,15)
1005 FORMAT(48HOBASIC VARIABLES/BASIS INVERSE/RIGHT-MANO-SIDE =)
1606 FORMAT(1H0,15,8E15.6/(6X,8E15.6))
                                                                               SI MP0 392
                                                                               SIMP0393
                                                                               SI MP0 394
1667 FORMAT(27H ENTER PHASE 2 ON ITERATION, 15)
                                                                               SIMP0395
1010 FORMAT (20HOLEAVING VARIABLE =, 15/
                                                                               SIMP0399
```

1 20HORIGHT-HAND-SIDE =,E15.6)	SINPO 404
1011 FORMAT(20H0 BASIC VARIABLES =.1615/(20x.1615))	SIMP0 401
1912 FORMAT (20 FORIGHT-HAND-SIDE =.6E 15.6/(2CX. EE15.6))	SIMP0 402
1013 FORMAT(43HOTHE PRIMAL PROGRAM HAS UNBOUNDED SOLUTION.)	SIMPO 403
1014 FCRMAT(2CHGENTERING VARIABLE =.15)	SIMPO404
1015 FORMAT (20HO UPDATED COLUMN =, EE 15 .6/(20x, 6E 15 .6))	SIMP0405
1016 FORMAT (45HO THE QUAL VALUE EXCEEDS THE BEST UPPER BOUND.)	SIMP0406
1017 FORMAT(55HO THE MAXIMUM NUMBER OF LP ITERATIONS HAS BEEN EXCEED	ED. ISIMPO407
1018 FORMAT (16HO BASIC VARIABLES)	SIHP0408
1019 FORMAT(17H0 VARIABLE/VALUE =,5(15,E15.6)/(17X,5(15,E15.6)))	SIMPO409
1620 FORMAT (35HO NON-BASIC VARIABLES AT UPPER BOUND)	SIHP0 410
1021 FORMAT (43HGNUMBER OF LP ITERATIONS THIS COMPUTATION = .15.	SIHP0 411
1 14H. CUMULATIVE =.15)	S1MP0412
1022 FORMAT (12H *****SIMPLE)	SI MPO 413
ENO	SIMP8414

```
SUBROUTINE SLOPES (NZ,NP, IR, IA, IS, IBV, NBV, IUPPER, TC, RMS, C2, C1, PJ, SLOPBCO1
1 XJ,SO,SI,B,NDI,NDZ,ND3,ND4,ND5,ND8)
C DETERMINE THE LEFT AND RIGHT SLOPES ASSOCIATED WITH THE OPTIMAL
                                                                                   SLOPODUZ
                                                                                   SLOPOGG3
C SOLUTION VALUE AS A FUNCTION OF A PARAMETER.
                                                                                   SLOPOCO4
      COMMON/P1/N, M, ITYPE, NSTRAT, NO [RL1, NBVRL1, NTITE1, NODRL2, NBVRL2,
                                                                                   SLOPOG05
                  NTITE2, MXLIST, LISTOP, ITAPE, IFB, MXITER, MBINV, IOUTPT,
                                                                                   SLOP0006
                  ITRACE, MSTART, TIME1, TOL1, TOL2, PCBUB, ALPHA (16)
                                                                                   SLOPOCU7
      COMMON/P2/EPSI, EPSIM, BIGN, BEGIM, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1H2, SLOPOGOS
                  NH1H3, N1P2, NP1, NSUH, NTC, H10
                                                                                   SLOPOGOS
     1
      COMMON/P3/NODNUT, LNOT, I BUBOP, LPFASE, NOORUL, NBVRUL, NTIGHT, NLIST,
                                                                                   SLOP0013
                  NLISTS, NFEAS, LSTMX, ITRTCT, ITRMAX, BLB, NBRNOD, PBRNOD,
                                                                                   SLOP0011
                  NBRVAR, NUPDWN, XBRNOD, TB FNOD, NODE, LNODE, Z, BOUNDL, BCUNDU, TSIG, IFEAS, IBRVR1, IUPON1, XBRVR1, IBRVR2, IUPDN2, XBRVR2,
                                                                                   SLOPOC12
                                                                                   SLOPOC13
                  L10, NITER, NJINV, M7, IPHASE, NPHASE, NM3M7, IALGO, IEGJ
                                                                                   SLOP0014
      DIMENSION IS (ND4), IBV (ND4), NBV (ND5), TUPPER (ND5)
                                                                                   SLOP0015
      OIMENSION PJ(NO4), XJ(NO4), SO(NO8), S1(NO8), B(NO4, NO4)
                                                                                   SLOPOC16
      IF (ITRACE.GE.1) WR ITE (6, 1002)
                                                                                   SLOPGC17
                                                                                   SLOPOC18
       DO 130 I= 1, M7
       IF (I.EQ.MP1) GOTO100
                                                                                   SLOPUC19
                                                                                   SLOPICEG
      S6 (I) =-816N
                                                                                   SLOPOCZI
       S1(I)=BIGA
  166 CONTINUE
                                                                                   SLOPOCZZ
      00150IPOS=1.L10
                                                                                   SLOP0523
       KIND=NEV(IPOS)
                                                                                   SLOPOC24
       DO110I=1, H7
                                                                                   SLOPOC25
  11C PJ(I)=0.0
                                                                                   SLOPOC 26
       CALL GETCOL (NZ,NP,IR,IA,IS,TC,RHS,C2,C1,PJ,ND1,ND2,ND3,ND4,ND5,
                                                                                   SLOPOL 27
                      KIND, NZEROS)
                                                                                   SLOPS[ 28
     1
      U01301=1,M7
                                                                                   SLOPOCZS
      Q1=0.0
                                                                                   SLOP0030
      00120J1=1.NZEROS
                                                                                   SLOPOC 31
      J=15(J1)
                                                                                   SLOP3C32
  120 Q1=Q1 + B(I,J)*PJ(J)
                                                                                   SLOPOC33
       Q1=Q1 + 3(I,MF1)*FJ(MP1)
                                                                                   SLOPGL34
      IF (IPHASE .EQ. 2)Q1=Q1 + B(I, MP2) "PJ(MP2)
                                                                                   SLOPOGSE
       IF (IUPPER (I POS) .EC. 1) Q1=-Q1
                                                                                   SLOPJC 36
  130 XJ(I)=Q1
                                                                                   SLCF0037
      IF (XJ(MP1).LE.EFSI)XJ(MP1)=0.0
                                                                                   SLOP0038
                                                                                   SLOP0039
       D0150I=1,M7
      IF (I.EQ. MP1) GOT 0150
                                                                                   SL OP3540
      IF (ABS(XJ(I)).LE.EPSI)GOT C150
                                                                                   SLOP0041
      X0=XJ(MP1)/(-XJ(I))
                                                                                   SLOP0C42
      IF (XJ(I).LT.EPSIM) GOTO140
                                                                                   SLOP0643
C SO(1) IS THE MAXIMUM CVER X(1,J).GT.O OF THE REDUCED COST DIVIDED
                                                                                   SLOP3044
G BY -X(I,J).
                                                                                   SLOPOC45
      IF (XO.LE.SO (I)) 60 TO 150
                                                                                   SLOP0046
      Sa (1) = XO
                                                                                   SLOPQC47
      GOT0150
                                                                                   SLOP0048
C S1(1) IS THE MINIHUM CVER X(1,J).LT.O OF THE REDUCED COST DIVIDED
                                                                                   SLOP0649
C by -x(I, J)
                                                                                   SLOP0650
  140 IF (XO.GE. S1 (I)) COTO150
                                                                                   SLOP0051
      S1(I)=X0
                                                                                   SLOF0052
  150 CONTINUE
                                                                                   SLOP0053
      IF (IOUTPT.LE.2) RETURN
                                                                                   SLOP0054
       WRITE (6,1000)
                                                                                   SLOP0055
      DO 16 0 I=1 . M7
                                                                                   SLOP0056
      IF (I.EQ.MP1 )GOT 0160
                                                                                   SLOPOS57
```

WRITE (6,1001) IBV (I), SC (I), S1 (I)	SLOP0058
160 CONTINUE	SLOP0059
RETURN	SLOP0C60
1000 FORMAT(1H0,2X,5HBASIC,11X,4HLEFT,12X,5HRIGHT/	SLOP0061
1 1X,8HVARIABLE,9X,5HSLOPE,12X,5HSLOPE//)	SLOP0062
1001 FORMAT (3X, 15, 3X, E15.6, 2X, E15.6)	SLOP0163
1002 FORMAT (12H +++++SLOPES)	SLOPJ064
END	SLOP0065

SUBROUTINE TIMEC	TIME 0 001
C PRINT THE ELAPSED TIME SINCE THE BEGINNING OF THIS JOB.	TIMEGOGZ
COMMON/P1/N.M.ITYPE,NSTRAT,NOORL1,NBVRL1,NTITE1,NOORL2,NBVRL2,	TIMEOCG3
1 NTITE2.MXLIST.LISTOP.ITAPE.IFB,MXITER,MBINV,IOUTPT,	TIME 4
2 ITRACE, MSTART, TIME1, TOL1, TOL2, PCBUB, ALPHA (16)	TIME OCC 5
COMMON/P2/EPSI, EPSIM, BIGN, BEGTM, M1, M2, M3, M4, N1, MP1, MP2, NM3, NM1M2,	TIME 0006
1 NM1M3,N1P2,NP1,NSUM,NTC,M10	TIME 0007
IF(ITRACE.GE.1)WRITE(6,1)_1)	TIMEDOCS
CALL SECOND (X)	TIME 0 009
X=X-BEGTM	TIMEOC10
HRITE(6,1000)X	TIME
RETURN	TIME 0012
1000 FORMAT (7HOTIME = ,F9.3,8H SECONDS)	TIME 0013
1001 FORMAT (11H *****TIMEC)	TIMEOC14
END	TIMEUL15

APPENDIX G

REFERENCES

- Robert S. Garfinkel and George L. Nemhauser, <u>Integer Programming</u>, John Wiley and Sons, Inc., New York, 1972.
- 2. Frederick S. Hillier and Gerald J. Lieberman, <u>Introduction</u> to <u>Operations Research</u>, Holden-Day, Inc., San Francisco, 1967.
- 3. Leon S. Lasdon, Optimization Theory for Large Systems, The MacMillan Company, London, 1970.

APPENDIX H
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